United States Court of Appeals

for the Second Circuit

APPENDIX

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NO. 74-2284 et al.

Nos. 74-2284, 74-2286, 74-2308, 74-2450, 74-2449

JOINT APPENDIX TO THE BRIEFS

VOLUME IX

IN THE UNITED STATES COURT OF APPEALS
FOR THE SECOND CIRCUIT

THE SOCIETY OF THE PLASTICS INDUSTRY, INC.,

HOOKER CHEMICALS & PLASTICS CORP.,

UNION CARBIDE CORPORATION,

TENNECO CHEMICALS, INC.

and

AIR PRODUCTS AND CHEMICALS, INC.,

Petitioners,

v.

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION,
UNITED STATES DEPARTMENT OF LABOR;
PETER J. BRENNAN, SECRETARY, DEPARTMENT OF LABOR;
and JOHN H. STENDER, ASSISTANT SECRETARY
FOR OCCUPATIONAL SAFETY AND HEALTH,

Respondents.

On Petition For Review Of An Order Of
The Occupational Safety and Health Administration,
United States Department of Labor

UNITED STATES COURT OF APPEALS
FILED
DEC 10 1974
SECOND CIRCUIT

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Figure 5 - Toward the innermost layer of the corium, the elastic fibers exhibit distinct to complete rarefaction, fragmentation and disintegration (elastic fiber staining).

instance, at rest), and carried out a cold-exposure test of the arms. In the case of the latter test, the lower arms of the patients were placed for 15 minutes under running tap water and the rewarming time was then determined. In five patients, who exhibited acroosteolysis and scleroderma-like changes, we carried out bilateral arm-hand arteriography using the transfemoral approach (Priv.-Doz. Dr. Betz, Institute of Radiology of the University; Professor P. Thurn, M.D., Director). Two other patients, because of the presence of Raynaud's phenomenon, were subjected to arteriography (in the one case by direct puncture of the brachial artery, and in the other one by using the transfemoral approach) in another hospital (Professor Dr. Schuessel and Professor Dr. Schober, Siegburg City Hospital). .10.

A capillary-microscopic examination of the finger-nail mantle (perionychium) was carried out in four patients; in each instance, the fourth finger of the left hand was subjected to that examination.

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Considering the possibility of the existence of generalized angiopathy, all patients were subjected to examination of the eye-ground, and four patients were subjected to ophthalmodynamometric examination (Ophthalmic Hospital, Professor W. Straub, M.D., Director; Bonn University).

Finally we have measured the blood pressure of all patients (reclining).

In six patients we found that the skin temperature on the hands was markedly reduced (up to 10°C below the normal value). In the cold-exposure test, rewarming time was prolonged in nine patients (up to 60 minutes); Raynaud's phenomenon could be induced in four of these patients, with the phenomenon involving either individual fingers or all of them.

Oscillographic and plethysmographic investigations yielded no findings indicating decreased blood circulation in the extremities.

Minor changes were found to exist on the finger arteries in the form of slight narrowing and constriction of the vessel lumina of the arteriae digitales palmares propriae and of the arteriae palmares communes. In isolated instances we found furthermore stenoses localized in segments. In one advanced case we were able to establish already delayed filling of the finger arteries. Almost all of these arteries exhibited diffuse and relatively uniform constriction. Severe stenoses to complete occlusions were found by us in the region of the basal and middle phalanges above all in fingers exhibiting acroosteolytic changes, while the other ones showed a distinctly more densely arranged vascular net. The vascular net, in fact, appeared to be particularly dense in the terminal finger phalanges in the acroosteolytic regions. Since the substance defect associated with acroosteolysis results in a shortening of the terminal finger phalanges, we are

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here probably dealing with an effect caused by compression of the arteries located in these regions. In patients exhibiting marked changes of this type, we found that the filling time of the finger arteries was clearly prolonged. The perfused finger arteries were highly constricted, and the lumina, in part, were obscured right to the periphery; collateral vessels could not be detected. In these cases, we found—in addition to severe stenoses—segmental occlusions of the finger arteries or even complete absence of filling of the arteries along the entire length of the respective fingers. The arteries of the palmar arches also exhibited constricted lumina, and the side branches could not be detected to different extents. The vascular changes described above did not reveal a definite correlation to either the number or the extent of the acroosteolytic processes. However, in the case of the fingers showing no acroosteolysis, we found that the vascular changes, on the whole, were less marked.

In the case of the two patients (Raynaud's phenomenon present without acroosteolysis), in whom arteriographic arm examinations were carried out in another hospital, the findings revealed the presence of constricted radial and ulnar arteries on both sides. The finger arteries, in part, were highly constricted, segmented or, in fact, completely occluded, with the middle and terminal phalanges being supplied with blood to an inadequate extent. The findings obtained in the right hand were more marked in character than those obtained in the left hand of a given patient. The arteriography of the left arm of the other patient [the authors actually do not state that the last few lines apply only to one of these two patients; Transl.] (transfemoral approach) revealed occlusion of the interosseous artery three

fingers' breadth proximal of the wrist. The arteries of the hand, on the whole, were considerably constricted, with the radial and ulnar arteries exhibiting strikingly constricted lumina. A detailed description of the angiographic investigations carried out is being prepared for publication.

Capillary-microscopic examination of the nail mantle revealed in all four patients investigated the existence of ampulla-like dilatations of the capillary loops of the type described in cases of Raynaud's syndrome (20). This particular finding was obtained in patients who, in fact, did exhibit clinical signs of disturbance of circulation, but no features of Raynaud's syndrome.

In two patients , the fundus of the eye exhibited increased meandering of the vessels; in a third one, it revealed the existence of a hypertonic state (blood pressure 145/85 mm Hg); and in a fourth one, it showed a distinct constriction of the arteries with slightly choked veins. The remaining six patients revealed no pathological findings on fundus examination. The ophthalmodynamometric examinations yielded pathological findings in two patients. One of them, in the reclining position, exhibited a tendency toward intracranial vascular spasms, while the other one exhibited an increase of intracranial vascular resistance.

The blood pressure was normal in nine patients (the systolic pressure varying between 100 and 140 mm Hg, and the diastolic pressure varying between 60 and 85 mm Hg). One patient exhibited slightly hypertonic values between 130/95 and 145/105 mm Hg.

We then realize that circulatory disturbances of the hands have represented a frequent symptom among the individuals investigated. The most

The most pronounced degree of these disturbances is reflected in Raynaud's phenomenon. Four patients, who clinically did not exhibit Raynaud's symptoms, did, however, yield pathological capillary-microscopic findings of the type described in cases of Raynaud's syndrome. The corresponding complaints voiced by the patients can be demonstrated by clinical means both by determining the rewarming time after exposure to coldness and by measuring the skin temperature after adaptation of the patient to room temperature.

The finding of normal oscillograms and plethysmograms in all our cases would appear to indicate that the cause of the reported complaints does not have to be looked for in the region of the large arm arteries. In fact, the arteriograms have revealed changes, in particular, in both the finger and hand arteries. These changes correspond to those observed in cases of Raynaud's syndrome of varying genesis (19), but the changes observed in our patients were considerably less distinctly pronounced than in cases of progressive systemic sclerosis. To the extent that we, on the basis of the small number of patients investigated so far, are able to assess the overall situation, it appears that there exists a positive correlation between the length of exposure to vinyl chloride and the extent of the angiographic findings. For instance, the must severe changes were observed in a patient, who had been exposed to the noxious agent for more than eleven years.

The eye-fundus findings obtained in six patients were not pathological in character; those obtained in the other four cannot be subjected to any kind of uniform interpretation.

The findings obtained by ophthalmodynamometric means revealed the existence of intracranial spasms and intracranial vascular resistance,

respectively, in two of the four patients investigated in that respect; this would then indicate that vascular changes of the type described in the case of the extremities take place also in the region of the brain.

3. Roentgenological investigations

Roentgenograms were obtained from all patients of the facial part of the skull, of the chest, and of the upper and lower extremities as well as of the shoulder and pelvic girdles. The pathological findings obtained are presented in Table 3.

The most striking changes—which hitherto have also been pointed out as the main symptom of 'occupational acroosteolysis'—were found in the hands of our patients: The hands of six patients exhibited typical stripe- or band-like osteolyses in the terminal finger phalanges; in a few cases, we found that the processus unguicularis separated from the bone by the osteolytic process exhibited fragmentation in addition to the former changes (Figure 6). That type of fragmentation was observed chiefly in fingers one to three of both hands. Six patients exhibited osseous defects along the margins of the processus unguiculares, and five, a diffuse atrophy of the hand bones. All terminal phalanges affected by the osteolytic process were shortened. One patient exhibited no acroosteolysis, but did show a distinct mushroom-like distension of the processus unguicularis, widening of the shaft (diaphysis) and shortening of the terminal finger phalanges. Furthermore there existed zones of condensation at the transition between the processus unguicularis and the shaft. The foot bones exhibited in four patients non-specific changes, like atrophy and minor marginal defects at the

Table 3 - Osseous changes found in ten patients suffering from the so-called vinyl chloride disease. Key: 1, Case No.; 2, Patient; 3, Hand bones; 4, Foot bones; 5, Other bones; 6, Osteoporosis (atrophy); 7, Marginal defects (Processus unguicularis); 8, Band-like osteolyses; 9, Arthritis; 10, Osteocysts; 11, Total.

Nr.	Patient	*Handskelet*			*Fußskelet*			*Übriges Skelet*	
		Osteoporose (Atrophie)	Randdefekte (Proc. ung.)	bandförmige Osteolysen (Endphalang.)	Osteoporose (Atrophie)	Randdefekte (Proc. ung.)	bandförmige Osteolysen (Endphalang.)	Arthritis	Knochencysten
1	S. G.	—	+	+	—	(+)	—	+	+
2	O. S.	+	+	+	+	—	—	—	+
3	D. Z.	+	—	—	—	—	—	—	—
4	J. F.	—	+	—	—	—	—	—	—
5	H. D.	—	—	+	—	+	—	+	—
6	A. W.	—	+	—	—	—	—	+	+
7	H. A.	+	+	+	—	—	—	—	—
8	M. C.	—	+	+	—	(+)	—	—	—
9	S. W.	+	—	—	+	—	—	—	+
10	K. H.	+	—	+	—	—	—	+	—
Summe		5	6	6	2	1 (2)	0	4	5

processus unguicularis; in one case, the foot bones exhibited a typical marginal separation of the processus unguiculares of both big toes. The iliosacral joints of four patients exhibited indistinct outlines and sclerosal indurations. In five patients, we found numerous translucent, i.e. cystic, areas in the regions of the head of the humerus and of the styloid process of the ulna. In addition to these patients, we have subjected to evaluation skeletal roentgenograms of 72 other PVC workers. In that evaluation we found in three cases osseous atrophy or osteoporosis, respectively, and in five cases minor marginal defects on individual processus unguiculares. A detailed presentation and discussion of these roentgenological skeletal changes will be published elsewhere (32).

Band-like osteolyses have been described by a great number of authors in the case of PVC workers (5; 7; 9; 10; 16; 36). The impressive picture

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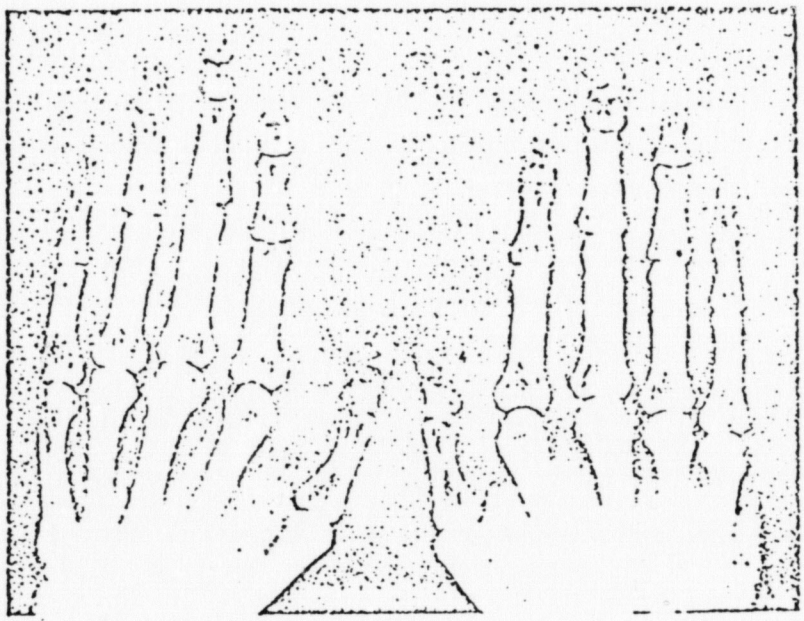

Figure 6 - Band-like osteolysis of the terminal phalanges of fingers 1 to 3 of both hands, and areas of cystic translucence in the terminal phalanx in the region of the processus unguicularis of the fourth finger of the left hand.

produced by these particular changes has given this disease its name in the Anglo-American literature. Acroosteolysis has been described furthermore in numerous other diseases. Acroosteolysis occurs, for instance, in cases .14. of familial osteolysis, dactylolysis spontanea (Ainhum), mutilating leprosy, syringomyelia, mutilating arthritis psoriatica, and in the acroosteolysis described by Von Harnasch. In the present connection, we are, however, permitted to neglect the latter conditions and diseases from the point of view of differential diagnosis (31; 32). Although band-like acroosteolysis has been described also in cases of progressive systemic sclerosis (2), differentiation between the latter disease and the disease under consideration is possible in an unequivocal manner (31).

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Data are available in the pertinent literature also on the aforementioned defects along the bone margins, the osteoporosis, and the sclerosal indurations of the ileosacral joints (10; 16). The question whether the striking frequency of cystic degeneration of osseous substance apparent in our patient collective is characteristic for the syndrome under consideration cannot be answered in any definite manner because of the relatively small number of patients investigated. A certain indication regarding the reversibility of acroosteolytic processes is found in the history of one of our patients followed for more than ten years, which history has already been published and discussed by us (23; 31). On the basis of that patient's history, it appears that the osteolytic process progresses in the terminal finger phalanges from distal to proximal. At the same time we see both a partial formation of osseous substance in the region of the processus unguiculares and a fusion of the "fracture pieces." The terminal finger phalanges remain shortened, and full recovery does not take place.

4. The hematopoietic system and blood clotting

The following tests and counts were carried out in all patients: Hemoglobin, hemoglobin E, erythrocytes, reticulocytes, leukocytes, differential, thrombocytes, and coagulogram (Institute of Experimental Hematology and Blood Transfusion Services; Professor H. Egli, M.D., Director).

The red blood counts yielded no pathological findings. Seven patients exhibited a mild reticulocytosis between 1.6 and 2.6 per cent. In four patients the leukocyte number was at the lower limit of the normal range (i.e. between 3200 and 3950 leukocytes/cu. mm.). The differential blood count

was modified in a definitely pathological manner in none of our patients. Examinations of the bone marrow did not yield signs indicating lesion of the hematopoietic system; in particular, the examinations did not reveal any signs indicative for osteomyelosclerosis or osteomyelofibrosis, respectively.

All ten patients exhibited a distinct thrombocytopenia. The thrombocyte (or blood platelet) values were repeatedly found between 63,000 and 119,000/cu.mm., with the lower limit of the normal value being 150,000/cu. mm.

Determinations of the plasma clotting factors yielded mostly normal values. In one patient we found that Factor VII was slightly decreased and Factor X was moderately decreased.

The most striking finding obtained in this set of tests and examinations was that the thrombocyte count was decreased in all our patients. The completely normal bone marrow findings had given no indication for a disturbance of thrombocytopoiesis. The thrombocytopenia established in these patients, thus, must be attributed—at least, in part—to the splenomegaly regularly present in these patients. In correspondence we would be permitted to interprete both the slight reticulocytosis evident in seven patients and the indicated leukopenia found in four patients in the sense of hypersplenism. A significant disturbance of the blood clotting mechanism could not be demonstrated on the basis of the factors investigated.

5. Liver and spleen

In their case histories, three of our patients had complained about recurrence of dragging and stabbing pains in the left epigastric region; .15.

one patient reported to have experienced both pain in the right epigastric region and sensations of fullness. Four patients denied any consumption of alcohol, while the other patients reported occasional consumption of beer and wine. No patient had been taking drugs on a long-term basis.

In the clinical examination we found that no patient exhibited a palpably enlarged liver; in three patients, when placed in right lateral position, we were able to touch the spleen at the level of the left costal arch or just below that arch.

In order to check liver function, we carried out the following laboratory tests: Erythrocyte sedimentation rate, electrophoresis, Takata [-Ara] test, bromsulphalein (BSP) test, serum glutamic oxalacetic transaminase (SGOT), serum glutamic pyruvic transaminase (SGPT), alkaline and acid phosphatases, serum lactic dehydrogenase (LDH), cholinesterase (ChE), serum bilirubin (both direct and indirect), plasma clotting factor, serum immunoglobulins, and complement fraction $\bar{S}_1A$.

All patients were subjected to roentgenological examinations of the stomach and intestines, including the barium meal (Institute of Radiology; Professor P. Thurn, M.D., Director), and liver and spleen scintigraphy (Dr. Schneider, Institute for Clinical and Experimental Nuclear Medicine; Professor C. Winkler, M.D., Director); and two patients were subjected to laparoscopy with directed liver punctures (Medial Out-Patient Hospital, Bonn University; Professor Kessler, M.D., Interim Director). With the aid of roentgenological examination of the esophagus, the stomach and the small intestine, it was possible in one patient to demonstrate the presence of esophageal varices. The scintigraphic examinations revealed in seven patients

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a distinctly enlarged spleen; in two patients, a slightly enlarged spleen; and only in one patient a spleen of normal size. The liver was enlarged in no case. The activity distribution pattern was diffuse in the region of the liver in all patients.

The erythrocyte sedimentation rate was normal in all cases even after repeated testing.

The total serum proteins were normal in seven patients, and their electrophoretic diagrams showed no pathological features. The three remaining patients exhibited a minor decrease of the β globulin fraction (to 5 to 7 per cent of the total).

The Takata [-Ara] test was normal in all ten patients. On the basis of the findings obtained with respect to the clotting factors in the plasma, it appeared in nine of these patients that hepatic synthetic activity was not restricted. One patient exhibited a slight decrease of Factor VII and a moderate decrease of Factor X. The cholinesterase exhibited normal activities in all cases. In nine patients, the serum transaminase values were in the upper region of the normal range or were slightly increased, respectively. These values were normal in one patient. Two patients exhibited increased acid and alkaline phosphatase values; one of these two at the same time exhibited increased lactic dehydrogenase and direct bilirubin values. A striking finding was the one showing that BSP retention—in contrast to the afore-presented relatively minor deviations—was slightly to markedly increased.

The histological examination of the liver biopsy specimens revealed in one case a slight periportal fibrosis, and in another one, a minor lesion

Table 4 - Clinical, biochemical, serological, scintigraphic and histological liver and spleen findings obtained in ten patients suffering form so-called vinyl chloride disease. Key: 1, No.; 2, Patient; 3, Splenomegaly (determined by scintigraphic means); 4, Esophageal varices; 5, β_1-A complement fraction (in mg per 100 ml.); 6, BSP retention (in % after 45 minutes); 7, Plasma clotting factors, electrophoresis, bilirubin, alkaline and acid phosphatases, LDH, ChE; 8, Liver biopsy material findings; 9, % of total; 10, Slight peri-portal fibrosis; 11, slight lesion of the liver parenchyma.

Nr. (1)	Patient (2)	Splenomegalie (szintigraph.) (3)	Oesophagusvaricen (4)	IgG (mg%)	IgA (mg%)	IgM (mg%)	β 1-A-Komplementfraktion (mg%) (5)	SGOT (mU/ml)	SGPT (mU/ml)	BSP-Retention (% n. 45 min) (6)	Plasmat. Gerinnungsfaktoren, Elphorese, Bilirubin, alkal. u. saure Phosphat., LDH, ChE (7)	Leberbiopsie-Befunde (8)
1	S.G.	+	—	3320	60	360	96	23	17	6,8	—	—
2	O.S.	+	—	3200	160	415	117	21	17	7,0	β-Globuline: 7 rel% (9)	—
3	D.Z.	—	—	2160	330	220	120	18	21	4,3	—	—
4	J.F.	+	—	1760	20	135	132	13	8	4,4	—	—
5	H.D.	++	—	4720	300	275	117	19	15	12,5	β-Globuline: 5 rel% (9)	—
6	A.W.	++	+	3320	190	355	117	19	17	15,1	β-Globuline: 5 rel% (9)	—
7	H.A.	+	—	3680	230	140	147	18	21	22,5	F VII 70%, F X 56%, LDH 216 mU/ml AP 68 mU/ml Bili. positiv	(9) leichte periport. Fibrose
8	M.C.	+	—	2720	480	275	141	23	23	25,6	AP 65 mU/ml SP 15,6 mU/ml	(9) leichte Leberparenchyschädigung
9	S.W.	+	—	1420	330	40	156	19	15	8,6	—	—
10	K.H.	++	—	960	370	200	126	21	23	18,4	—	—

Additional Key: F, Factor; AP, alkaline phosphatase; SP, acid phosphatase; ChE, cholinesterase.

of the hepatic parenchyma. No signs were found indicating either active inflammatory processes or cirrhotic transformation of parenchyma. The more important findings obtained have been summarized in Table 4.

On summary consideration of all the findings relating to liver function we are able to state: The serum transaminases are almost regularly increased in these cases to a slight extent. That finding may be regarded as a sign indicating a minor participation of the liver parenchyma in the pathological

process under consideration, and this, in particular, because there were no deviations from the normal values in the electrophoretic results (apart from a decrease in the β globulin levels in several patients), in the plasma clotting factors, in the serum enzymes (lactic dehydrogenase, alkaline and acid phosphatases, and cholinesterase), and in the serum bilirubin concentration in eight of our patients. In two patients we detected, as a sign indicating participation of hepatic parenchyma, transitory increases of both alkaline and acid phosphatases in one of these two, and increases in both serum lactic dehydrogenase and alkaline phosphatase with weakly positive serum bilirubin in the other one. Among the laboratory results obtained, we find that the normal albumin--γ-globulin ratios in association with normal values for total proteins found in all our patients speak against the presence of any chronic liver injury as well as against a cirrhotic process. The histol gical findings obtained also did not provide any indication for either fatty degeneration or cirrhotic transformation of parenchyma, since the structure of the hepatic parenchyma was found to be entirely normal. .17.

In connection with the other liver function data, we have difficulties explaining the moderate increase of BSP retention amounting to 12 to 26 per cent, which was observed in five of our patients. That retention cannot be explained by the minor increases of the levels of serum glutamic oxalacetic and serum glutamic pyruvic transaminases. With respect to differential diagnosis we would have to consider a fatty liver or congestion of the congestion of the liver. However, clinical indications for the latter pathological conditions are missing in these patients; furthermore, the histological findings presently available do not indicate the presence of a fatty liver,

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and the roentgenological findings do not provide indications suggesting congestion of the liver due to right heart failure.

BSP excretion provides information on the excretory efficiency of the liver cell. However, since the ability of the liver cell to remove that dye depends also on liver blood flow, we would be justified to some extent to think in the case of "so-called vinyl chloride disease" that a decrease of liver blood flow caused by the existing periportal fibrosis leads to a delayed removal of BSP.

The—with one exception—regularly found splenomegaly must, in our view, also be considered in close association with the hepatic alterations. We have available no indications at all for the existence of splenomegaly within the framework of any acute inflammatory disease. One could most readily think in the present context of a splenomegaly associated with portal hypertension due to intrahepatic factors, i.e. of a so-called hepatic block. On the basis of the histological findings showing the existence of periportal fibrosis, we would then be dealing with an intrahepatic, presinusoidal block. Measurements of pressure (blocked hepatic-vein pressure and intrasplenic pressure), in fact, have not been carried out in our patients, but the largely not, or at best only slightly, impaired liver function as well as the normal structure of the hepatic parenchyma in conjunction with the absence of cardiac failure speak against the presence of a postsinusoidal block. Since only one of our patients exhibited formation of hepatofugal circulation with development of esophageal varices, we would be permitted to assume that the pressure is not significantly increased in the portal vein of the other patients. Despite that situation, the changes

already
in the liver, could lead to a presinusoidal block with secondary splenomegaly, since there exists no strict correlation between portal pressure and spleen size, and since splenomegaly may be present in cases where portal hypertension is as yet not present (4). .18.

Splenomegaly, in turn, leads to hypersplenism—i.e. a condition where the spleen is overactive in regulating the numbers of blood cells in the circulation leading to a lack of formed elements in the peripheral blood—which is indicated in our patients by an intensification of the existing thrombocytopenia, by a tendency to leukopenia and, occasionally, by a slight reticulocytosis. On the basis of the findings presently available, we are unable to determine whether this splenomegaly is based originally only on a presinusoidal block or also on fibrotic processes in the spleen itself.

6. Lungs

In all our patients, we established detailed case histories taking into account their smoking habits, carried out clinical examinations, and made roentgenograms of their chest. All ten patients were subjected to resting spirometry and whole-body plethysmography, and nine patients were subjected to a blood-gas analysis (Professor Schwabe, University Medical Hospital; Professor H.J. Dengler, M.D., Director).

In the course of the clinical examinations, we found in one patient—as evidence indicative for pulmonary emphysema—that the percussion revealed a depressed diaphragm, which moved little with respiration. In another patient, the chest roentgenogram revealed increased lung markings on both sides of the chest and a thickening of the left hilum. The roentgenograms of the other nine [sic!] patients revealed no pathological findings.

In the investigation of pulmonary function (spirometry, whole-body plethysmography) we found in eight patients signs indicating chiefly restrictive changes.

As an expression of partial insufficiency we found in five patients a slight to moderately severe hypoxemia, with the P_{O_2} values going down to 62 mm Hg.

The existence of partial insufficiency in conjunction with the spirographic findings indicating chiefly restrictive changes speaks for the presence of a disturbance of diffusion of the type seen in the early stages of diffuse pulmonary fibrosis. There then arises the question whether there might exist changes in the pulmonary tissues similar to those found already in the collagenic and elastic fibers of the dermal connective tissue.

7. Immunological findings

The following serological investigations have been carried out in all our patients: Determinations of the immunoglobulins IgG, IgA, and IgM as well as of the complement fraction β_1A using the technique of radial immunodiffusion; tests for antinuclear factors (University Medical Hospital; Professor H.J. Dengler, M.D., Director) and LE [lupus erythematosus] cells; tests for the presence of CRP [C-reactive protein], streptococcal antibodies (ASL [antistreptolysin] titer), rheuma factors (latex and Waaler-Rose tests), and cold agglutinins. In addition, we have subjected our patients to both the direct and the indirect Coombs test and serological tests for syphilis (Wassermann's test: Complement binding reaction with cardiolipin, and complement binding reaction with bovine heart extract; flocculation reactions: Venereal Disease Research Laboratory test, and Meinicke's Flocculation Test II).

As is demonstrated by the findings presented in Table 4, all patients exhibited deviations in the respective immunoglobulin fractions: One of the patients exhibited an increased IgG level; three patients, increased IgG and IgM levels; two patients, increased IgG, IgA and IgM levels; one, increased IgA and IgG levels; and one, only an increased IgA level. One patient exhibited a slight IgA level increase simultaneously with a slight IgM level decrease; in one patient, IgA was decreased. In three patients we found that the complement fraction β_1A was at the lower limit of the normal range; in one patient, that fraction was slightly decreased. Antinuclear factors and the LE cell phenomenon could be demonstrated in no case. All other tests carried out yielded normal findings.

Since antinuclear factors and LE cells and positive rheuma tests were obtained in no case under investigation, and since, furthermore, the erythrocyte sedimentation rate, the electrophoretic studies and the CRP test yielded no signs at all indicating the existence of acute inflammation, we would be permitted to exclude the presence of an autoimmune disease in our patients.

The deviations found in the respective immunoglobulin fractions could be related most readily to an existing liver parenchyma lesion. The IgA and IgM values obtained corresponded to the levels we see in patients with non-inflammatory fatty liver and inactive or moderately active chronic alcoholic hepatitis or cirrhosis (13; 14). On comparison with the latter syndromes, we find, however, that the IgG levels found in our patients are clearly elevated reaching values we also see in active alcoholic cirrhosis of the liver. It would then appear that the changes in the immunoglobulin fractions in conjunction with the findings outlined above in the Section dealing with our

liver and spleen findings represent the expression of a chronic, toxic liver injury with inflammatory participation of the hepatic mesenchyma, with that participation varying in gradual degrees. The low values found in four patients for complement fraction $\beta_1 A$ are worthy of note; however, considering the other findings obtained in our tests, we are hardly in a position to consider a complement-fixing process in the elucidation of our findings. We could more readily assume that this particular globulin is formed in a less abundant manner due to the liver parenchyma injuries existing in the respective cases (30).

8. Additional findings

Apart from the laboratory tests already discussed further above, our patients were subjected to tests for fasting blood glucose, non-protein nitrogen, creatinine, uric acid, sodium, potassium, calcium and chloride; urine specimens were examined for protein, glucose, bile pigments and pH; and the urinary sediment was evaluated. All these tests and examinations yielded normal values.

The results obtained in a detailed neurological examination of these patients will be reported elsewhere in due course.

9. The so-called vinyl chloride disease without acroosteolysis and clinical skin changes

The clinical and internal findings obtained in the ten patients so far subjected to detailed investigation drew our attention to three other patients, who, to be sure, exhibited neither clinical skin changes nor

acroosteolysis, but whose internal findings nevertheless corresponded to .20.
a surprising extent to the findings obtained in the syndrome presently under consideration.

Case histories

F.S., 52 years old, since 1957 working in the autoclave room of a PVC factory. Since the early sixties, the patient has been complaining about frequent spells of dizziness and drowsiness; in more recent years, he has been complaining about a feeling of strong pressure in the epigastric region as well as about aversion against fatty foods. --- Until about two years ago, the patient suffered from a distinct sensitiveness to coldness of the fingers and, to a lesser extent, of the feet. --- May 16, 1972: Bleeding esophageal varices. May 18, 1972: The patient is admitted to the University Surgical Hospital, in Bonn. The laboratory findings obtained there at that time showed: Thrombocytes, 73,000/cc. mm; electrophoresis, no pathologic findings; slight increase of plasma clotting factors V, VII, and X. Roentgenographic examination: The barium meal revealed esophageal varices in both the middle and the lower thirds of the esophagus as well as varices at the fundus of the stomach. --- Percutaneous splenoportography: Intrahepatic block; collateral circulation by way of the coronary vein of the stomach. --- June 8, 1972: Splenectomy is carried out with institution of a spleno-renal anastomosis. Liver and spleen findings obtained during the course of surgery: The spleen is markedly enlarged; the liver shows a slightly uneven surface, but not one corresponding to a typical cirrhosis. There are no distinct signs indicating existence of portal hypertension. The pressure is only slightly increased in the omentum, the veins, the liver,

and the spleen. Macroscopic and microscopic findings on the liver [biopsy specimen] and the spleen (Institute of Pathology; Professor P. Gedigk, M.D., Director): Liver: In addition to a minor, circumscribed fatty infiltration, there exists a slight fibrosis of the portal fields; any definite statement regarding the etiology of that fibrosis is no longer possible at this time. There exist no signs indicating either a chronic hepatitis or cirrhotic transformation of parenchyma. Spleen: The spleen weighs 300 g and measures 15 by 7 cm. Histological examination reveals chronic blood congestion in the spleen (so-called fibro-adenia of the spleen). Sections through the hilum of the spleen reveal a freshly separated thrombus inside of the splenic vein. After surgery, the thrombocyte count rose to 540,000/cc. mm.[1]

Follow-up examinations have been carried out by us since October 5, 1972. Thrombocytes, 97,000/cc. mm.; total proteins, electrophoresis, no pathological findings; serum transaminases, in the region of the upper normal values (i.e. SGOT, 17 and 19 mU/ml.; SGPT, 15 mU/ml.); both acid and alkaline phosphatases slightly increased (acid phosphatase, 15 and 12 mU/ml.; alkaline phosphatase, 79 and 83 mU/ml.). BSP test, 16.7 per cent retention after 45 minutes. Serological tests: CRP, weakly positive; IgG, 2960 mg/100 ml.; IgA, 820 mg/100 ml.; IgM, 220 mg/100 ml.; complement fraction β_1A, 99 mg/100 ml. Pulmonary function tests and blood-gas analysis reveal signs indicating moderate restrictive disturbance of ventilation, a moderate pulmonary emphysema, and partial insufficiency. Measurements of temperature (arms): On both hands, distal of the wrists, there exists a temperature deficit,

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[1] We are indebted to Professor A. Guetgemann, M.D., Director of the Surgical Hospital, for making this case history available to us.

which amounts to between 4 and 7°C at the terminal finger phalanges. Histological findings obtained in a biopsy specimen taken from the right hand: Narrowing of the epidermis and basophilic degeneration of the collagenic fibers in the upper corium as a sign of senile degeneration. The middle and lower coria exhibit no far-reaching changes in the collagenic and elastic connective tissues.

L.M., 51 years old, has been working for eleven years in all rooms of a PVC factory, but cleaned autoclaves only rarely. In 1962, the patient went to a sanatorium in consequence of cardiac complaints and backaches. At that time, the clinical liver and spleen findings showed non pathological aspects. Since 1968, the patient has been complaining about increasing pains in the left epigastric region, and spleen enlargement is known to exist since that time.

In 1969, the patient underwent examinations in the Medical Out-Patient Hospital as well as in the Surgical Out-Patient Hospital: Splenomegaly; disturbance of liver function reflected in a BSP retention of 10 per cent after 45 minutes; otherwise, however, the liver values determined in the laboratory indicated no pathological processes to be taking place. Among the other laboratory values, only electrophoresis revealed a deviation from the normal values with a moderate increase of the β globulins to 15.4 per cent of the total. Biopsy material taken by sternal puncture: No pathological findings. Roentgenological examination of the extremities: No signs indicating osteomyelosclerosis. The causes of the existing splenomegaly could not be elucidated. University Surgical Hospital: Intrahepatic block, probably associated with liver parenchyma injury with beginning formation of esophageal and pyloric varices (splenoportography; liver and spleen scintigrams).

In 1970, the patient was again examined in the Medical Out-Patient Hospital: Roentgenological examination revealed that the spleen was more enlarged than in 1969; thrombocytopenia with values being between 46,000 and 81,000 thrombocytes/cc. mm.; BSP test: 5.3 per cent retention after 45 minutes. The remaining laboratory values, including those indicating liver function, were within the normal range. Laparoscopy: Pronounced splenomegaly. The liver, on the whole, is not enlarged and exhibits a brownish-red color. A delicate wavy surface relief strikes the eye; that surface represents a somewhat colorful pattern due to capsular fibrosis and distinctly accentuated blood-vessel and lymph-vessel markings. Definite signs for parenchymal transformation are not in evidence. Liver tissue histology: Moderately pronounced periportal fibrosis. No statement can be made with respect to the genesis of these findings.

Esophagoscopy: Beginning esophageal varices. Biopsy material taken by sternal puncture: No pathological findings.

In October of 1972, the patient was examined in our Hospital: History: Continuing pains in the left epigastric region, and this, in particular, when bending over and after meals. Spells of dizziness and of staggering occur daily and may last for up to 1.5 hours. The power of hearing has decreased. Pronounced inner restlessness. Clinical findings: Palpation reveals that the spleen reaches down almost to the left crest of the ilium. Otherwise there are no deviations from the normal findings. Laboratory results: Normal red cell count; reticulocytosis of 1.6 per cent [of erythrocytes]; leukopenia with 2350 leukocytes/cc. mm.; normal differential count; thrombocytopenia with 30,000 thrombocytes/cc. mm. Liver function and chemistry:

Total proteins, electrophoresis, Takata-Ara test, SGOT, SGPT, alkaline and acid phosphatases, direct and indirect serum bilirubin were all within the normal range. BSP test: 13 per cent retention after 45 minutes. Clotting factors: Slightly prolonged thrombin time; prothrombin, Factors VII and X, moderately decreased. Serological tests: IgA, 600 mg/100 ml.; IgG, 1600 mg/100 ml.; IgM, 200 mg/100 ml.; complement fraction β_1A, 84 mg/100 ml. LE cells, antinuclear factors and cold agglutinins were not detected. CRP, ASL, latex fixation, Waller-Rose test, and the classical serological tests for syphilis yielded no pathological findings. Pulmonary function tests (spirogram, whole-body plethysmogram, blood-gas analysis): Indications for restrictive disturbances of ventilation with moderate partial insufficiency. Barium meal: Indications for mild esophageal varices; esophagogastric hiatal hernia; deformed duodenal bulb; enlarged spleen; no signs for either ulcer or tumor in the stomach and the duodenum. Histological findings made in a biopsy specimen taken from the back of the right hand: The lower corium exhibits at some sites thickened collagenic fibers and pronounced rarefaction of the elastic fibers. Otherwise, there were no particular findings.

B.K., 47 years old, working since 1954 in a PVC factory, where he was engaged as autoclave cleaner for about 1.5 years between 1954 and 1956 and again for three months in 1968; otherwise mostly engaged in screening. The patient is suffering from increased sensitiveness to coldness and frequent shaking of the hands, since one to two years ago. Since two to three years ago, he has been suffering spells of syncopal dizziness and drowsiness. Since four to five years ago, he feels very tired and is slow and forgetful; his libido has decreased. --- The patient does not smoke. --- In 1969,

the patient suffered from a bleeding duodenal ulcer with tarry stools. He again produced tarry stools in April of 1970 and in October of 1972. Because of repeated hemorrhages during the course of hospital-ward treatment, two thirds of the stomach were removed by surgery after Billroth II; there was abundant discharge of ascites during surgery. Liver: Macroscopic findings: Cirrhosis-like changes; microscopic findings (Institute of Pathology; Professor P. Gedigk, M.D., Director): Slight increase of the connective tissue, and diffuse round-cell infiltration of the portal fields. No signs indicating either chronic hepatitis or cirrhotic transformation of liver parenchyma. .22.

The patient was admitted to the Bonn University Dermal Hospital between December 11, 1972, and December 21, 1972. Clinical examination: Spleen distinctly palpable below the left costal arch; otherwise, no important pathological findings. Laboratory results: The red cell count reveals a mild hypochromic anemia with normal differential count; thrombopenia (90,000/cc. mm) with slightly prolonged thrombin time and decrease of Factor X. Liver function and chemistry: BSP test, 15.6 per cent retention after 45 minutes; electrophoresis, serum transaminases, LDH, alkaline and acid phosphatases, bilirubin, iron and copper in serum within the normal ranges. Other investigations: Electrolytes, non-protein nitrogen, classical serological tests for syphilis, no pathological findings. Roentgenological examinations (barium meal): Esophageal and fundus varices. Liver and spleen scintigraphy: Pronouncedly atypically shaped liver with enlarged left lobe. Spleen considerably enlarged with strongly increased colloid storage. Pulmonary function tests and blood-gas analysis: Moderate pulmonary emphysema, partial insufficiency. Measurements

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of temperature: Temperature deficits distal of both wrists at the terminal finger phalanges, > 10°C Histological findings obtained in a biopsy specimen taken from the back of the right hand: Orthohyperkeratosis, narrowed epidermis. All collagenic fibers in the lower and middle corin exhibit both striking deficiency in nuclei and homogenization, which become more pronounced with increasing depth. Elastica staining, on the other hand, reveals elastic fibers showing no pathological findings. (End of Case histories.)

All three patients had been working for eleven to eighteen years—i.e. for a relatively long time—in the same PVC factory, changing working places from time to time within the plant. During the last few years, these men had been complaining subjectively about spells of drowsiness, dizziness, sensations of pressure or pain in the epigastric region, and increased sensitiveness of the hands to coldness.

Although some of these subjective complaints had also been voiced by the other ten patients investigated by us, we find that a far greater agreement exists between the former group of ten patients and these three patients with respect to the internal findings obtained during clinical examination. For instance, two of these three patients exhibited deficient blood flow through the hands as indicated by measurements of hand temperature, and all three exhibited decreased arterial oxygen saturation as an expression of a partial insufficiency of the lungs, with the pulmonary function tests providing indications for the existence of both restrictive disturbances of ventilation and pulmonary emphysema.

However, three specific findings are particularly impressive in the case of these three patients viz. the distinct thrombocytopenia (with one

patient simultaneously exhibiting a leukopenia); the pronounced enlargement of the spleen; and the liver injury. The latter injury was reflected in all three patients in the results of the laboratory tests, i.e. in a distinctly increased retention of BSP, with only one of these three patients exhibiting at the same time slightly increased levels of serum transaminases and alkaline phosphatase. The deviations in the clotting factor concentration, those in the immunoglobulin fractions as well as the decrease in the concentration of the complement fraction β_1A also corresponded to the findings obtained in the first group of ten patients.

From the point of view of pathological anatomy, the liver of all three patients on inspection with the naked eye exhibited a delicately waved surface relief, with one of these men, in addition, exhibiting capsular fibrosis and increased blood-vessel and lymph-vessel markings. The histological examination revealed in all three cases a more or less strongly marked fibrosis of the periportal fields, which had led to an intrahepatic block (demonstrated in one patient with the aid of splenoportography) and, in consequence, to the formation of esophageal and gastric fundus varices.

These characteristic liver changes, in conjunction with the marked splenomegaly and thrombocytopenia as well as the disturbances of pulmonary function, on the one hand, have led to the conclusion that we are dealing here with cases of so-called vinyl chloride disease and, on the other one, indicate the grave prognosis of this disease in its more advanced stages. Thus, two of our patients have suffered hemorrhages from varices located in the esophagus or in the fundus of the stomach, respectively, for which reason, in one patient, spleno-renal anastomosis had to be instituted following

splenectomy, and, in another patient, two thirds of the stomach had to be removed by surgery. The progressive character of this disease is made evident in the case of the third patient, who hitherto has not yet suffered from bleeding esophageal varices. In the course of the last three years that patient has shown a further enlargement of the spleen; his thrombocytopenia has become more distinct; and, in addition, he has acquired a leukopenia.

The finding showing that the latter three patients—with marked injuries of the parenchymatous organs—exhibited neither the clinical and histological skin changes typical for the so-called vinyl chloride disease nor acroosteolysis can, perhaps, be explained by the type of work they carried out within the process of PVC manufacture—an aspect we will discuss in some detail in the next Section.

III. Conditions prevailing at the working place

What then would be the suspected cause of the disease described in the present paper? That question can be answered only if we subject the production of polyvinyl chloride from vinyl chloride as well as the other substances used in the manufacture of this polymer and the secondary and intermediate products to close scrutiny.

The initial material used in the manufacture of PVC, viz. vinyl chloride —first prepared in 1833—is a colorless gas at room temperature (boiling point, -13.9°C; freezing point, -154°C), heavier than air, and possesses an aromatic odor. In the gaseous state, vinyl chloride is readily inflammable. Its narcotic or anesthetic action has been stressed already a long time ago .24. (29). Vinyl chloride, however, could not be employed as anesthetic agent,

since the concentrations required to bring about anesthesia caused disturbances of cardiac rhythm (28).

Exposure of rats and guinea pigs to the effects of VC at a concentration of 30 per cent by volume for 30 minutes led, by way of an anesthtic stage, to the death of these animals (26). Autopsy of these animals revealed pulmonary congestion, pulmonary edema, congestion of blood in both the liver and the kidneys as well as decreased blood coagulation. In long-term VC exposure experiments at low concentrations (200 p.p.m. daily for seven hours over six months) using rabbits, Torkelson et al. (34) found centrolobular degeneration and necroses with foamy vacuolization in the liver as well as periportal, cellular infiltration. It has recently been reported (35) that prolonged exposure (12 months) of rats to the effects of VC led to skin, lung, and bone tumor development.

Acute intoxication due to VC in the manufacturing plants has been observed only rarely [reported only rarely?]. There exists a report (11) on two workers, who experienced reversible dizziness, light disorientation and burning of the feet after being exposed for three minutes to the effects of VC at a concentration of between 2 and 5 percent.

Three cases of accidental intoxication are known from Canada, where VC gas was twice determined to represent the cause of intoxication (8). The symptoms were pronounced dizziness and dopiness in two of these cases as well as decreased blood coagulation. One of these two victims died. The third one died, while he was cleaning a tank for ten minutes. The exact circumstances surrounding the death of the latter man could not be determined. On the skin, VC led to toxic changes in the sense of second degree burns (15).

On the basis of the animal-experimental findings described above, the maximal allowable (or admissible or acceptable) concentration (MAC) was fixed in 1970 [in the Federal Republic of Germany] at 100 p.p.m. (18).

In the polymerization of VC to PVC, we know a number of different basic processes, with each one, in turn, having been modified numerous times (6). The suspension procedure represents the process most commonly used. In that procedure, deionized water is given into the reaction container (the autoclave or reactor) followed by numerous additives. Among the latter are suspending agents like polyvinyl alcohol, methyl cellulose and gelatin, emulgators (sulfonated oils), surface-active agents (sorbitol monolaureate) and buffering solutions (for instance, sodium bicarbonate). In addition, trichloroethylene may be added in order to obtain polymers of low molecular weight. Catalysts (chiefly organic peroxides) are used to initiate the reaction.

Once the reactor has been closed and evacuated, liquid VC is pumped into it under pressure. This reaction mixture is agitated with the aid of a rotating propeller and heated to 50 to 55°C by heating the reactor wall. Since polymerization takes place with emission of heat, the product must subsequently be cooled. Depending on both the degree of polymerization and the desired molecular weight of the final product, the process is interrupted and the excess VC is pumped into a gasometer for subsequent re-use.

Up to that point in the manufacture of PVC, processing has taken place in a closed system, from which, under normal circumstances, gases cannot escape; however, during the subsequent processing of the reaction mixture as well as during the cleaning of the reactor, VC and other gaseous substances inevitable escape and are then inhaled by the workers.

Following removal of the VC gas by means of suction, the reaction mixture is pumped from the reactor into a mixer, where excess VC still present is once more removed with the aid of a vacuum pump. The reaction mixture is then transferred into a storage container, from which the centrifuges are then fed. The polymer is separated from the aqueous phase in these centrifuges. Next the polymer is dried in drying drums, and then separated in screening machines according to particle sizes. The finished, powdery white polymer is finally packed into paper bags or transported off in tank vehicles. .25.

Once the reaction mixture has been pumped out, the reactor is opened and squirted out with water using a high-pressure gun. If it is not clean after that procedure, the reactor is filled with water. After the water has been discharged again, one or two workers climb into the reactor in order to remove the material—which frequently is very hard—coating the walls with the aid of spatulas or, if necessary, with that of hammers and chisels. The so-called autoclave workers, however, are not engaged exclusively with servicing the autoclaves, but they also assist in the centrifugation, the drying and screening, and the packing of the finished polymer product.

In addition to the suspension procedure described above, the factory, in which the workers investigated by us were employed, uses the emulsion procedure. The latter procedure is used to manufacture not only the homopolymer PVC, but also the mixed polymer polyvinyl chloride-vinyl acetate. Polymerization again takes place in a reactor; however, in contrast to the suspension procedure, certain additional substances (emulgators) are employed. Following removal of the gas on conclusion of the reaction, the

reaction mixture is not transferred into centrifuges and drying machines as in the case of the suspension procedure, but, by way of storage tanks, is sprayed through jets inside a tower containing hot air. The polymer mass contained in the sprayed emulsion droplet is directly dried and then separates out on filters. The gases contained in the reaction mixture and water (which has become steam in the heat inside the tower) are vented. Screening and packing of the polymer are carried out as in the case of the suspension procedure.

In the course of the processes leading to the polymerization of VC to PVC, VC as well as other gaseous compounds reach the air in the manufacturing halls. For instance, in the course of each autoclave cleaning with the aid of the water-spray gun, residual gases still present inside the autoclave reach the working room. Although no results of measurements on the concentrations of the gaseous compounds in the working rooms are available, we may safely assume that we are dealing here with considerable concentrations. In fact, at times concentrayions are reached, which elicit in the autoclave workers a prenarcotic syndrome consisting of dizziness, dopiness and nausea.

However, there also occur gas concentration, which can be detected by means of the gas odor, at the centrifuges, the storage and mixing tanks, and at the spraying tower; gases escape also from the delivery pipes as well as from the drying and screening equipment. Furthermore, the workers are exposed to these gases while cleaning the inner wall of the reactor with spatulas and chisels, i.e. gases either released from the precipitate coating the walls or present cavities within the polymerized precipitates. Concentrations between 50 and 100 p.p.m. have been measured after venting of the

reactor (6). Analysis of air samples taken close to the inner wall of the reactor, i.e from the area to which the workers' hands and face are exposed, yielded concentrations between 600 and 1000 p.p.m. / / .26

However, the largest quantities of gas escape due to leakage (for instance, at the valves) from the charged reactor (these leakages can be fixed only after the reaction process has been completed) as well as due to insufficient removal of VC following completion of polymerization. Hitherto only a few publications are available on the degree of purity of the VC introduced into the reactor and on the qualitative and quantitative composition of the gases present inside the reactor following completion of the polymerizing reaction. However, there can be no doubt that the greater part by far consists of VC. The chemical analysis of the residual gases from a reactor (the polymerizing procedure employed in that instance has not been reported) yielded the following composition: Vinyl chloride, 90%; carbon dioxide, 8.5%; and small quantities of vinyl acetate, trichloroethylene and nitrogen, and traces of argon (8).

IV. Discussion

In the present paper we have presented a detailed description of the results obtained in the investigation of thirteen workers employed in a PVC factory. We have been able to describe for the first time a number a grave findings seen in different organ systems (cf. Table 5). Our findings suggest that the syndrome characterized by our findings can no longer be adequately described by the term hitherto used, viz. 'occupational acroosteolysis.'

All the individuals investigated by us exhibited a moderate to severe thrombocytopenia. Twelve of these patients exhibited a moderate to pronounced

Table 5 - Summary presentation of the most important findings obtained in all patients suffering from the so-called vinyl chloride disease. Key: 1, Case No.; 2, Patient; 3, Dermal changes; 4, Clinical skin changes; 5, Histological skin changes; 6, Circulatory disturbances; 7, Osseous changes; 8, Thrombocytopenia[a]; 9, Splenomegaly[b]; 10, Liver changes; 11, Disturbances of pulmonary ventilation and/or diffusion; 12, esophageal varices; 13, Periportal fibrosis; [a]: +, 150,000 to 90,000/ul.; ++, 90,000 to 50,000/ul.; +++, < 50,000/ul.; [b]: +, enlargement to the costal arch; ++, enlargement below the costal arch; +++, enlargement beyond the naval area; 14, Total.

Nr. (1)	Patient (2)	Hautveränderungen (3): a) klin. (4)	b) histol. (5)	Durchblutungsstörungen (6)	Knochenveränder. (7)	Thrombocytopenie[a] (8)	Splenomegalie[b] (9)	Leberveränderungen (10)	Ventilations- u./o. Diffusionsstörungen (11)
1	S. G.	+	+	+	+	+	+	+	+
2	O. S.	+	+	+	+	+	+	+	+
3	D. Z.	—	+	+ (R)	—	+	—	—	—
4	J. F.	—	+	+ (R)	—	+	+	—	+
5	H. D.	+	+	—	+	++	++	+	+
6	A. W.	+	+	—	+	++	++	+	—
7	H. A.	+	+	+ (R)	+	++	+	(12) Oespohag. Var. + (13) portale Fibr.	+
8	M. C.	+	+	+	+	+	+	+	+
9	S. W.	+	+	+ (R)	—	+	+	+	+
10	K. H.	+	+	—	+	+	++	+	+
11	L. M.	—	+	—	—	+++	+++	+ (12) Oespohag. Var. (13) portale Fibr.	+
12	F. S.	—	—	+	—	+	++	+ (12) Oesophag. Var. (13) portale Fibr.	+
13	B. K.	—	+	+	—	+	++	+ (12) Oesophag. Var. (13) portale Fibr.	+
Summe (14)		8	12	9	7	13	12	11	11

splenomegaly. On the basis of our laboratory results, we have been able to demonstrate in eleven patients a certain restriction of liver function, which, in histological terms, corresponds to a perportal fibrosis. Four patients exhibited esophageal varices, caused by this periportal fibrosis and the resulting portal hypertension.

The changes found in the respiratory tract were encountered strikingly frequently. The majority of the patients (i.e. eleven of them) exhibited both functional disturbances in the sense of a partial insufficiency and signs indicating the existence of restrictive changes.

Circulatory disturbances in both the hands and the feet, including Raynaud's phenomenon, were reported by almost all patients to have represented the first symptom of their present condition; in eleven cases, it was possible to demonstrate these disturbances by clinical means. The scleroderma-like skin indurations in the region of the arms typical for this disease have been observed by us in eight patients; however, there existed no strict correlation between the extent of the circulatory disturbance and the prominence of the dermal changes.

Acroosteolyses, which have given the disease its name, in particular, in the American literature, were found by us in six patients. Hitherto, authors have assigned a central position to acroosteolysis and Raynaud's phenomenon within the framework of this syndrome. Other authors have established that between three and five per cent of the workers employed in PVC factories will contract this disease. Related to the two symptoms, Raynaud's phenomenon and acroosteolysis, we are able to confirm the morbidity; however, taking into consideration our own internal and clinical findings, we believe that we are permitted to assume with the greatest certainty that the morbidity actually is considerable greater than that. In the case of the individuals investigated by us—despite the fact that we so far have carried out no mass examinations of workers employed in that factory—we have concluded that morbidity already amounts to ten per cent of the workers of that factory employed in the manufacture of PVC. Considering these data, we are easily able to discard the suggestion voiced by several authors viz. that constitutional factors play a significant role in the development of this syndrome. In the first instance we must rather think of the occurrence

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of a toxic process. A process of that type is indicated, on the one hand, by the morbidity among chiefly young men employed in a very special occupational sector, and, on the other one, by the complex nature of the syndrome. Despite the different distinction of the syndrome in the individual case—with dermal and osseous changes occupying the foreground in the one instance, and internal findings in the next one—we are able to find one common feature in all cases: In all the organ systems investigated by us we have always found changes in the connective tissue or in the vascular connective tissue, respectively.

Particularly impressive connective-tissue changes are found in the liver. Due to a multiplication of the collagenic fibers, there develops a fibrosis of the portal fields, with otherwise normal parenchymal structure. Compared to the latter findings, we realize that the minor toxic changes in the hepatic parenchyma occupy the background of the syndrome. The question whether the enlargement of the spleen should be regarded as the sole consequence of portal hypertension or whether primary fibrotic events take place in the spleen cannot yet be determined at the present time. The four patients suffering from the most pronounced splenomegaly exhibited esophageal and, in part, gastric fundus varices.

The cause of the thrombocytopenia remains unclear. It is certain that it cannot be attributed to either the splenomegaly or the hepatic changes, since that deficiency was a constant symptom in an individual after splenectomy as well as in a patient exhibiting no liver or spleen changes. On the basis of our findings we would like to assume that the decreased number of thrombocytes represents the first symptom of this syndrome that can be

demonstrated by clinical means. That finding is all the more worthy of note, because the thrombocyte count represents a parameter readily determined, and there would then exist the possibility to carry out mass examinations inside factories.

Indications for the occurrence of fibrotic processes in the pulmonary tissues are found in the existing restrictive disturnace of ventilation in combination with hypoxemia. On histological examination, the skin exhibits both an increase and a thickening of the collagenic fibers with simultaneous destruction of the network of elastic fibers. The corium vessels exhibit only discrete changes in the form of edematous swelling. In comparison to the latter findings, angiography—above all, when carried out in the region of the hand and finger arteries—reveals constrictions and segmental stenoses. Perhaps, the osteolyses of the terminal finger phalanges could be explained on the basis of the latter findings as an expression of a trophic disturbance. Circulatory disturbances in the sense of Raynaud's phenomenon—which existed also in four of the patients investigated by us—are found, in addition to numerous other internal disorders, also in progressive systemic sclerosis as well as in consequence of toxic action (17). In fact, the finding of Raynaud's phenomenon in conjunction with the clinical and histological changes of the skin remind the physician of that systemic disease, and we know that both the vessels and the connective tissues occupy decisive positions in the pathogenesis of progressive systemic sclerosis. Although we thus find, on the one hand, distinct parallels between progressive systemic sclerosis and the 'so-called vinyl chloride disease,' it is, on the other hand, well possible to distinguish between these two syndromes (23). Above

.29.

all, there exists no doubt that the disease described by us is an occupational one, having a toxic cause. As we have outlined in detail further above, the patients are continuously exposed to the effects of gases in their factory—gases released in the course of industrial PVC preparation. These gases represent a mixture of numerous volatile substances. The greatest part by far is made up by vinyl chloride (8). The other substances, like vinyl acetate and trichloroethylene, are present only in traces. The narcotic or anesthetic effect of VC is well known. In their respective case histories, the workers investigated by us have stated that, at various places along the production line, the concentrations of VC gas at times were so high that its inhalation elicited a feeling of dizziness, drowsiness and nausea.

The fact that VC in corresponding concentrations has a hepatotoxic effect is known on the basis of results obtained in animal experiments, which results, among other factors, have led to a refixing of the MAC value (8).

Furthermore, the occurrence of Raynaud's phenomenon has been observed in workers employed in plants, which manufacture only the monomer, and not PVC (1; 27). Very recently a report has been published stating that prolonged exposure of animals to the effects of VC led to disturbances of bone formation (3).

Several authors have stated that work in the autoclave is of decisive importance with respect to the subsequent appearance of acroosteolysis, Raynaud's phenomenon and skin changes. Hitherto no patient had been known to suffer from occupational acroosteolysis, who had not at least for a while worked as autoclave cleaner. These authors have suggested that this disease is caused by the concurrence of, first, a substance having toxic effects

.70.

either following inhalation or across the skin; secondly, the physical alteration of the hands during the process of cleaning the autoclave; and, thirdly, a constitutional factor. We, on the other hand, assume, in the case of manual autoclave cleaning, that the microtraumatization of the hand surface (which really is not very constant in character) represents a factor of lesser importance in connection with the occurrence of osteolysis than the close contact with the polymerisate precipitates, which still contain relatively large quantities of VC gas about to be released into the atmosphere by means of diffusion; release of these quantities of VC gas may result in VC concentrations along the inner wall of the autoclave (even after preceding rinsing with water) amounting to between 600 and 1000 p.p.m. A further indication pointing to the percutaneous penetration of VC is reflected in the finding showing that we have observed scleroderma-like skin changes only in the region of skin not covered with clothing.

On the basis of both the findings presented and the considerations outlined in the present paper, we believe that we must strongly suspect that long-term exposure to the effects of VC may elicit a complex syndrome. That syndrome is characterized by fibrotic transformation of the parenchymatous organs--the lungs, the liver, and the spleen--as well as in the skin and in the vascular system. This syndrome then possesses the character of a systemic disease, associated with a prognosis that is grave in the more advanced stages. These pathological changes then are far more extensive than the syndrome of 'occupational acroosteolysis' already described. We therefore would like to separate the present syndrome from this symptom-associated description and propose the name "vinyl chloride disease."

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Translation of non-English and non-French bibliographical items

1. Anghelescu, F. et al. Clinical-pathological considerations on Raynaud's disease in workers of the vinyl chloride industry.

2. Contributions to the radiology of "acrosclerosis."

4. Clinical hematology.

13. and 14. Quantitative immunoglobulin determination in the serum in cases of inflammatory liver disease.

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17. Primary and secondary Raynaud's syndrome.
18. Materials involving occupational hazards. Toxilogical basis of MAC values.
19. Angiographic examination of vascular changes due to vibration.
20. Peripheral circulatory diseases as reflected in microcirculation.
21. Scleroderma-like dermal changes, Raynaud's syndrome and acroosteolysis in workers engaged in the manufacture of vinyl chloride.
22. and 23. Clinical aspects of the so-called vinyl chloride disease.
24. Scleroderma and associated connective-tissue problems.
25. Histopathology of the skin.
31. Band-like osteolysis in the terminal phalanges of th[illegible]d bones.
32. Skeletal changes in cases of so-called vinyl chlor[illegible]ease.
33. Suciu, I. et al: Contribution to the study of dise[illegible]s produced by vinyl chloride.

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DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
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ATLANTA, GEORGIA 30333

August 26, 1974

Mr. John H. Stender
Assistant Secretary of Labor
Occupational Safety and
Health Administration
U.S. Department of Labor
Washington, D. C. 20210

Dear Mr. Stender:

Your letter of August 15 just now reached me. Enclosed is a copy of our presentation concerning vinyl chloride liver tumors, as given at the May meeting in New York.

Sincerely yours,

Clark W. Heath, Jr.

Clark W. Heath, Jr., M.D., Director
Cancer and Birth Defects Division
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Enclosure

CHARACTERISTICS OF CASES OF ANGIOSARCOMA OF THE LIVER AMONG VINYL CHLORIDE WORKERS IN THE UNITED STATES*

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*Presented at the Working Group on Toxicity of Vinyl Chloride-Polyvinyl Chloride, New York City, May 10-11, 1974

The relationship between vinyl chloride exposure and human angiosarcoma of the liver (ASL) first received serious attention in December 1973 when a case of this rare tumor was diagnosed at autopsy in a vinyl chloride (VC) worker from the B.F. Goodrich chemical plant in Louisville, Kentucky. At that time, this case represented the third recognized among VC workers at this plant; prior cases had been diagnosed in May 1970 and March 1973. (1) While at first the possibility was considered that case occurrence might be unique to the Louisville facility, the subsequent detection of cases at three other plants has shown the problem to be industry-wide. Ten additional cases have subsequently been identified among other VC polymerization workers in the United States (Table 1). Workers at a total of four different plants have been involved.

The earliest case recorded to date occurred in 1961, the others being scattered over subsequent years, five in the past two years 1973-74. In several instances, the diagnosis of ASL was not specifically made until review of pathologic material during the early months of 1974. Death certificate diagnoses in such cases indicated "primary liver cancer," and in one instance merely "liver cirrhosis." The three most recent cases were diagnosed in the course of systematic medical screening, two at the Louisville plant in February 1974 and one at the South Charleston plant in May 1974. These three patients are the only ones of the thirteen who are currently alive.

All thirteen cases have occurred in white males. About half have been in their 40's with an age range from 36 to 60 years and a mean age at time of diagnosis of 48.2 years. Length of time between first VC work and diagnosis has ranged from 12 to 29 years (mean 20.3 years), mean total duration of VC work being 18.0 years.

Comparison of Observed and Expected Incidence

The reason an etiologic association between VC work and tumor could be so readily inferred on the basis initially of just three cases is because ASL is extraordinarily rare. Based on data from the National Cancer Institute's Third National Cancer Survey (1969-1971), expected annual incidence of this tumor is on the order of 0.0014 case per 100,000, or about 25-30 cases a year in the entire U.S. population. Estimating the total VC worker population past and present in the U.S. at roughly 20,000 persons (an estimate which may be too high), one can calculate that only about 0.03 case of this tumor might be expected in such a population over a decade. Since thirteen cases have thus far been identified (and it is not unreasonable to think that others may yet be found among other VC workers), one arrives at a risk ratio, (a ratio of observed to expected cases), of at least 400 to 1.

Needless to say, had the situation concerned a common tumor such as lung cancer, the picture would have been much less clear cut and would have required many more cases and much more elaborate epidemiologic manipulation to associate tumor with industrial VC exposure.

Clinical Features

Medical and epidemiologic data have been examined in detail for cases at the Louisville plant in particular. The remainder of this presentation summarizes these and other data concerning VC workers at that plant. For each Louisville case, all available medical records have been reviewed. Interviews have been held with each surviving patient and with close relatives of all deceased patients to obtain specific information concerning work history,

toxicologic exposures, and family history. Pathologic material, particularly sections of liver and of tumor, have been reviewed both by local pathologists in Louisville and by Dr. Louis Thomas at the National Cancer Institute and Dr. Hans Popper at The Fogarty International Center.

In most cases the diagnosis of ASL was reached only with difficulty; three of the five fatal cases were not diagnosed until autopsy. In only one of the two remaining fatal cases was ASL diagnosed unequivocally prior to death (four months). In the other case, a diagnosis of "primary liver cancer" was made five months before death, but ASL was not clearly identified until recent review of autopsy material.

Presenting signs and symptoms varied widely and were relatively non-specific. Abdominal mass was a presenting feature in four cases, GI bleeding in two (diagnosed initially in each instance as peptic ulcer), fatigue and weakness in four, and noticeable weight loss in one. In one case no signs or symptoms referable to cancer or liver disease were present and the diagnosis was made only in the course of workup for another health problem.

Duration of symptoms prior to diagnosis ranged from one to eleven months for five of the six cases displaying symptoms. In the sixth case, symptoms related to liver disease antedated diagnosis of tumor by eight to ten years. In that particular case, a diagnosis of liver fibrosis was made in May 1965 following two episodes of gastrointestinal bleeding in the course of two years. A portocaval shunt operation was performed because of varices, splenomegaly and increased portal vein pressure. Six years later (May 1971) the patient was re-evaluated because of progressive symptoms, and at that time,

liver scans suggested the presence of tumor. ASL, however, was not unequivocally diagnosed until autopsy in March 1973.

At time of tumor diagnosis, physical findings among the seven cases varied considerable. In two cases, no abnormal findings at all were recorded. Three cases presented with liver enlargement, in each instance by splenomegaly. In a fourth case, splenomegaly alone was detected. One additional case presented with severe right upper quadrant tenderness in the absence of clear cut organomegaly. Laporotomy revealed free blood in the peritonial cavity traced to what was tentatively diagnosed prior to death as "hemangioma of the dome of the liver."

Abnormalities of one or more liver function tests were present in every case at or around the time of diagnosis. In most instances, however, these abnormalities did not become clear-cut until the terminal phases of illness. SGOT values were at least mildly increased in all seven cases, total bilirubin in six and alkaline phosphatase in five. LDH was increased in four of six cases tested and BSP in one of two.

Diagnoses were made with the help of liver-spleen scanning in six cases and hepatic angiogram in two. Esophageal varices were demonstrated in two cases, one by x-ray, the other by endoscopy. Efforts at tissue diagnosis were made by open liver biopsy in all seven cases and by needle biopsy in three; autopsies were performed in four of the five deceased cases. Open liver biopsy provided a diagnosis of tumor in four cases while in the remaining three cases, diagnosis was made only at autopsy.

Recent review of pathologic material in all seven cases has shown evidence of portal fibrosis as well as of tumor. In addition, discrete subcapsular fibrotic areas were described at time of open liver biopsy in one of the two cases diagnosed in 1974. In two cases, angiosarcoma was present in tissues other than liver. In one the picture was that of local tumor spread.

Epidemiologic Features

The B.F. Goodrich Louisville plant employs about 1,200 persons of whom about 270 or 20 per cent are engaged in VC polymerization activities. The plant first began polyvinyl chloride (PVC) production in 1942 after pilot operations dating from 1937. The present polymerization work force size was reached in the late 1950's. All seven patients had worked in jobs directly related to VC polymerization, and in this capacity all seven can be assumed to have had direct exposure to vinyl chloride monomer (VCM). Initial involvement in VC work occurred from 12 to 28 years prior to tumor diagnosis (mean 20.0 years) (Table 1). Involvement was essentially continuous during these years (mean duration of VC work 17.0 years). Dates of initial industrial VC exposure ranged from 1944-45 soon after the plant began production (two cases), to as recently as 1957 and 1961. Ages at initial exposure ranged from 23 to 33 years (mean age 27.6 years).

Although the data are far from conclusive, they do suggest a possible dose-response relationship when one tries to compare intensity of VC exposure with latent period. Virtually everyone entering VC polymerization work at the Louisville plant starts as a "helper," a job which includes cleaning the interiors of polymerization vats and hence involves a maximum exposure to VCM.

When duration of work as a "helper" (a rough measure of VCM exposure) is correlated with interval between first exposure and diagnosis, an inverse relationship is suggested. For three cases averaging only 5.3 months as "helpers," exposure-to-diagnosis intervals averaged 22.0 years; for the four remaining cases averaging 36.5 months as "helpers," this interval was 14.5 years.

No evidence was found that exposure to other potentially hepatotoxic materials outside the work place played any consistent role in these particular cases. Only two patients had a history of increased alcohol intake, and in one the increase was borderline. One man gave a history of exposure to arsenic insecticides for several years as a teenager. In none was there any suggestion of thorium dioxide exposure. Acroosteolysis, past or present, was not observed in any case.

Non-malignant Liver Disease

Because two of the three tumor cases which were initially recognized in Louisville had shown evidence of hepatic fibrosis antedating or coexisting with tumor, medical records at the Louisville plant were reviewed for cases of non-malignant liver disease. A total of four such cases have been identified to date, again all among VC workers.

The clinical and epidemiologic features of these four cases closely resemble those of the seven tumor cases (Table 2). All were white males, average age 46.5 years at time of first diagnosis. One was diagnosed in 1968, one in 1972, and two in 1973. VC work began on the average 20.8 years prior to diagnosis and in every instance was continuous. One patient, however, a 28-year-

old man, had worked at the plant for only six years. Duration of illness prior to diagnosis ranged from 0 to 7 months. While three of the four patients presented with significant splenomegaly (one with hepatomegaly in addition), in one case physical examination was entirely negative. A variety of liver function tests showed abnormalities although none were severe and no consistent patterns were evident. In two cases esophageal varices were demonstrated, and in both instances, splenorenal shunt operations were performed. All three patients with splenomegaly underwent splenectomy.

Open liver biopsies were performed in all four cases. In each instance, a picture of portal fibrosis was seen accompanied by the observation in three cases of discrete nodules of subcapsular fibrosis. The latter feature was indistinguishable pathologically from the subcapsular lesions observed in one of the seven tumor cases.

Discussion

In light of recent animal experiments (2) and of clinical observations reported in European VC workers (3), it seems likely that exposure to VCM in the course of VC polymerization work is responsible for malignant and non-malignant liver disease in these cases. Epidemiologic features further suggest that either prolonged exposure and/or a long interval from initial exposure is required before liver disease becomes apparent. While the length of time involved seems quite variable (6 to 29 years), in all but one case the interval was twelve years or longer.

We have no assurance, however, that the actual latency required for development of liver disease (as opposed to latency in relation to clinical recognition) may not be considerably shorter. Unfortunately, if one can judge by the clinical features of the Louisville cases, manifestations of liver disease are quite variable, and in most instances were not detected until the process of hepatic fibrosis was so far advanced that splenomegaly and increased portal pressure had already been produced. Furthermore, if one envisions angiosarcoma as a late manifestation of the same pathologic process, then it seems even more likely that clinical detection of liver disease lags considerably behind actual disease onset. At present, therefore, a major concern is to develop more sensitive means for detecting liver disease, not in its late malignant phase (if in fact a single pathologic spectrum is involved), but in the early stages when fibrotic reaction first sets in.

Eventually, non-malignant liver disease, not ASL, may prove to be the most prominent disease problem associated with VCM exposure in terms of numbers of persons affected. One must also consider the possibility, however, that VCM may produce angiosarcoma at sites other than liver or that tumors of other kinds may also be induced. At present, animal experiments suggest that a wide spectrum of tumors may be involved (1), although as yet there is no clear human evidence to support the concept. In addition, no human cases of liver disease, whether fibrosis or frank angiosarcoma, have yet been strongly linked to VC exposure outside the industrial setting. While this may mean that risk of disease is greatly reduced or even non-existent at very low levels of

VC exposure, it is obviously too early to draw any conclusions. In view of past experience with other oncogenic chemicals, it will be prudent, until much more data have been assembled, to view any exposure to VCM as potentially harmful.

Summary

A total of 13 cases of ASL have been documented to date among VC workers in four different plants in the U.S. In this particular industrial population, this number of cases represents at least a 400-fold increase over expected incidence for this extremely rare tumor. The first case occurred in 1961. Average age at diagnosis is 48.2 years. Average length of time between initial VC work and diagnosis has been 20.3 years.

A detailed review of seven cases associated with one plant revealed that clinical features varied from little or no overt illness prior to diagnosis to advanced liver disease with portal hypertension and marked splenomegaly. Portal fibrosis was present in all seven of these ASL cases as well as in four additional cases with non-malignant liver disease among VC workers at the same plant. These findings suggest that exposure to VCM in industrial settings can produce hepatic fibrosis with angiosarcoma as a late manifestation. Conventional liver function tests may not be sensitive indicators of such liver impairment, at least in its early stages.

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Table 1. Cases of Angiosarcoma of the liver (ASL) among vinyl chloride workers in the United States

Name of company	Location of plant	Age at diagnosis, race, sex	Month and year of first vinyl chloride work	Month and year of diagnosis	Month and year of death	Number of years between first vinyl chloride work and ASL diagnosis	Total years in vinyl chloride work
B.F. Goodrich	Louisville, Ky.	52 WM	6-44	4-64	4-64	19	18
B. "	"	43 WM	7-52	8-67	1-68	15	15
"	"	36 WM	11-55	5-70	9-71	14	13
"	"	49 WM	12-48	3-73	3-73	24	16
"	"	58 WM	11-45	12-73	12-73	28	28
"	"	45 WM	1-62	2-74	---	12	12
"	"	43 WM	5-45	2-74	---	28	17
Goodyear	Niagara Falls, N.Y.	40 WM	10-46	4-61	8-61	14	14
G. "	"	54 WM	6-51	5-68	5-68	16	16
"	"	60 WM	10-46	3-70	3-70	23	23
Union Carbide	S. Charleston, W. Va.	45 WM	8-44	3-68	3-68	23	18
U "	"	52 WM	8-44	4-74	---	29	29
Firestone	Pottstown, Pa.	50 WM	9-49	5-69	5-69	19	15
F							

Table 2. Cases of non-malignant liver disease among Louisville vinyl chloride workers

Age at diagnosis, race, sex	Month and year of diagnosis	Number of years between first VC work and diagnosis	Clinical features: enlarged spleen	Clinical features: enlarged liver	Clinical features: abnormal liver function tests*	Pathologic features: Portal fibrosis	Pathologic features: Subcapsular fibrosis
46 WM	12-68	24	+	-	AP, BSP, SGOT	+	+
28 WM	1-72	6	+	+	TB, SGOT	+	+
56 WM	9-73	24	+	-	TB, AP	+	-
56 WM	9-73	29	-	-	TB, LDH, SGOT	+	+

*AP = alkaline phosphatase
BSP = bromsulphalein clearance
SGOT = serum glutanic oxalacetic transaminase
TB = total bilirubin
LDH = lactic dehydrogenase

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Section of Occupational Toxicology

1974-07-05

Nancy Beach, Ph D
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U S A

Dear Doctor Beach,

At the VC/PVC conference in May in New York you asked for a copy of the manuscript on my presentation of the two possible Swedish cases of angiosarcoma. The manuscript is hereby enclosed.

Yours sincerely,

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Assoc. Professor

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Two [illegible] in a Swedish [illegible]

by

David [illegible], M.D., KemaNord AB,
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Industry

Vinyl chloride monomer (VCM) and polyvinyl chloride (PVC) resin is manufactured by one Swedish company, KemaNord AB, which today runs two plants. The plant at Stockvik, near Sundsvall in northern Sweden, started VCM synthesis and PVC resin manufacture during 1945 and is still manufacturing PVC resin from the monomer. The synthesis of VCM was moved to a new plant in southern Sweden in 1963. At the same time some old polymerization reactors were taken down at Stockvik. The hygienic conditions were apparently greatly improved in the Stockvik plant in 1968.

The PVC resin is manufactured by the suspension, emulsion and bulk methods. In 1973 the PVC-production amounted to about 60 000 tons at the Stockvik plant. KemaNord AB does not manufacture plastic goods from PVC resin. The total number of workers employed on a long time basis (i.e at least two months employment) since 1945 at the VCM/PVC-plant at Stockvik is estimated to around 620.

Air concentrations of VCM in the working environment have not been measured until recently. Between 1945 and 1968 workmen are however said to occasionally have shown objective signs on very high exposure levels. Air concentrations in the polymerization plant are today 18-20 ppm VC on an average in the reactors rooms and under 5 ppm in drying and packing departments.

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Case reports

Case 1 was a male born 1937. He was employed [illegible] in the year 1951. From the year of employment until the debute of the disease at 43 years age in 1980 he was an operator of the PVC polymerization. His time of employment was 18 years.

At time of admission Case 1 had lost 20 pounds of weight and showed up with splano- and hepatomegaly, slight anemia (Hb 9,3 %) and a moderate elevation in erythrocyte sedimentation rate (65 mm), gamma-, elevated alkaline phosphatase (98 units) and slightly elevated GPT (52 units). α-fetoprotein was, however, negative.

Nine months after debute of symptoms a liver tumor was confirmed after angiography. The patient was operated and cytological examination indicated primary hepatocellular cancer. The liver was perfused several times with fluorouracil. A second operation was performed and the patient died about one year after the debute of symptoms.

At post mortem examination the liver tumor of Case 1 was diagnosed as a low differentiated primary liver carcinoma. The pathologist did, however, discuss the possible presence of a non-typical angiosarcoma. After a recent reevaluation of the pathologic specimens angiosarcoma could not be excluded.

Case 2 was a male born in 1911. He was employed in the year 1945. From the date of employment until 1968 he only worked with VCM production. From 1968 until the debute of the disease at 61 years age in 1972 he probably had a low, or a very low, exposure to VC. His time of employment with exposure to VC was 23 to 27 years.

At time of admission Case 2 had lost weight, and showed up with a palpable epigastric tumor, slight thrombocytopenia (104 000 cells/mm^3), slightly elevated alkaline phosphatase (22 units) as well as transaminases (GOT 75 and GPT 25 units) and lactic dehydrogenase (955 units).

Angiosarcoma of the liver in workmen occupied in VCM/PVC resin manufacture in Sweden should be seen against the background of the incidence of angiosarcomas in the liver among the total Swedish population (8 mill. inhabitants, 1972). In the official cancer register a total of 16 cases of primary liver cancer (site 155.0) were histologically classified as angiosarcomas (PM 300) from the start of the register 1958 until end of 1969. Four of those 16 cases were babies, five were men and seven were women. Among the professions registered no association to industrial work can be found. It is to be noted that the register from 1970 until date is not complete and thus considered not reliable.

The two Swedish cases of suspected angiosarcomas were first classified as primary liver cancers. The conclusion drawn from that is that the real number of angiosarcomas associated with manufacture of VCM and PVC resin in this country and maybe also in foreign countries may be larger than hitherto observed. An epidemiological study of various populations at risk in Sweden should be performed. During such a study primary liver cancers, and cancers of other sites, should be looked for. Such studies are under way.

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TABLE 1

CONFIRMED CASES OF LIVER ANGIOSARCOMA AMONG WORKERS EXPOSED TO VINYL CHLORIDE OR POLYVINYL CHLORIDE

COUNTRY	CASE #	BIRTH DATE	1st VC or PVC EXPOSURE	DX ANGIO-SARCOMA	AGE AT DX	YRS 1st EXP TO DX	TOT YRS EXP	DATE OF DEATH
VC MONOMER PRODUCTION WORKERS								
Sweden	02	11-27-11	00-00-45	05-15-72	61	27	23	08-16-72
POLYMERIZATION WORKERS								
Czechoslovakia	01	AWAITING DETAILS						
Czechoslovakia	02	AWAITING DETAILS						
Great Britain	01	00-00-01	00-00-46	12-00-72	71	26	20	12-00-72
Norway	01	12-23-15	03-00-50	12-20-71	56	22	21	01-04-72
Sweden	01	06-23-27	08-14-51	02-00-70	43	19	18	10-20-70
United States	01	00-00-22	12-09-48	03-00-71	49	22	16	03-03-73
United States	02	00-00-34	11-15-55	05-00-70	36	14	13	09-28-71
United States	03	00-00-15	11-28-45	12-00-73	58	28	28	12-19-73
United States	04	00-00-24	07-06-52	08-00-67	43	15	15	01-07-68
United States	05	00-00-12	06-19-44	04-00-64	52	20	18	04-09-64
United States	06	00-00-29	01-17-62	02-00-74	45	12	12	ALIVE
United States	07	05-03-22	08-00-44	00-00-68	45	24	18	03-23-68
United States	08	05-06-20	10-07-46	08-00-61	41	15	15	08-29-61
United States	09	00-00-31	05-23-45	03-01-74	43	29	17	ALIVE
United States	10	08-16-13	06-00-51	05-00-68	55	17	17	05-10-68
United States	11	05-27-09	10-14-46	03-00-70	61	23	23	03-16-70
United States	12	11-17-18	09-13-49	05-00-69	50	20	15	05-02-69
United States	13	12-01-21	08-19-44	05-00-74	53	30	30	07-04-74
W. Germany	01	07-26-31	10-14-57	00-00-71	40	14	14	12-14-71
W. Germany	02	06-04-30	10-01-57	00-00-69	39	11	11	01-25-69

Note: '00' indicates unknown date

189c

COMPOUNDERS, FABRICATORS, ETC

United States	14	00-00-13	08-18-38	06-00-73	60	36	00	07-03-73	Note 1
United States	15	00-00-25	00-00-00	07-00-72	47	00	00	02-15-73	Note 2

OTHER VC EXPOSURE

W. Germany	03	00-00-00	00-00-00	00-00-00	43	14	00	00-00-00	Note 3

Note 1 Machine operator covering electrical wire with PVC plastic insulation
Note 2 Accountant at several fabrication plants (work history under review)
Note 3 Filling sprinkler cans with fluid containing VC fuel (Pesticide bombs Propellant

Note: '00'=indicates unknown date

FINAL ENVIRONMENTAL IMPACT STATEMENT

PROPOSED REGULATION
VINYL CHLORIDE

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION
DEPARTMENT OF LABOR

FINAL ENVIRONMENTAL IMPACT STATEMENT

PROPOSED REGULATION
VINYL CHLORIDE

Prepared by:

Department of Labor
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Room 500, 1726 M Street, N.W.
Washington, D.C. 20210

Date Draft Environmental Statement Available: June 12, 1974
Date Final Environmental Statement Available: September 5, 1974

( ) Draft (x) Final

Environmental Impact Statement for Vinyl Chloride

U.S. Department of Labor
Occupational Safety and
Health Administration
Office of Standards Development
Room 500, 1726 M Street, N.W.
Washington, D. C. 20210

1. Name of action. (x) Administrative action.
   ( ) Legislative action.

2. OSHA proposes to regulate producers of vinyl chloride, polyvinyl chloride, and articles made from these substances by requiring that their employees not be exposed to vinyl chloride above specified levels. The purpose of this regulation is to reduce the risk of contracting cancer among workers so exposed.

3. The major impact of the regulation is expected to be a reduction in the number of workers contracting liver angiosarcoma and other forms of cancer. A concomitant adverse impact is expected to be substantial increases in capital and operating expenditures among manufacturers, along with reduced productivity. The effect of these cost increases will be increased prices for products made from vinyl chloride and polyvinyl chloride.

4. Major alternatives considered along with the proposed standard include a reduced scope and coverage of the standard, higher permissible levels of exposure, and additional time permitted for companies to meet certain provisions of the standard.

5. See Appendix C for Federal, State, local agencies, and other parties who have commented on the draft environmental impact statement.

6. Draft available to Council on Environmental Quality and public on June 12, 1974. Final available to Council on Environmental Quality and public on September 5, 1974.

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I. SUMMARY

Vinyl chloride (VC), a flammable compressed gas, is the raw material from which the polymer, polyvinyl chloride (PVC), is constructed. Polyvinyl chloride serves as the basis for a wide variety of plastic products that find useful application in virtually every walk of life. Since it was first produced in 1930, vinyl chloride, in the form of polyvinyl chloride, has become one of the most basic raw materials in the economy. Today, over 5.4 billion pounds (2.43 million metric tonnes) of vinyl chloride and over 4.4 billion pounds (1.98 million metric tonnes) of polyvinyl chloride are consumed annually, with future growth only limited by available supplies of feedstock and production capabilities.

Vinyl chloride resin is produced in 37 U. S. plants. PVC resins are compounded with additives to yield materials of various specifications in approximately 200 plants, and the compounded resins are processed into finished or semi-finished products in several thousand fabricating plants. The semi-finished products serve as components for a large number of consumer products made in an unknown number of plants. Polyvinyl chloride eventually finds its way into many products used in building and construction (such as flooring and piping), apparel, electrical wiring, home furnishings, packaging, recreation, and transportation.

In January 1974, information came to light that vinyl chloride is a possible carcinogen and may have caused the deaths of several workers, all of whom had been exposed to the chemical in polymerization plants. Since previous knowledge had indicated that VC was a relatively harmless gas outside of its high flammability, this news initiated attempts on the part of industry, labor, and government to define the extent of the hazard. Preliminary information indicated that the main hazard was experienced by workers in companies producing ~~or using~~ vinyl chloride or (producing) polyvinyl chloride. Accordingly, the Occupational Safety and Health Administration conducted a fact-finding hearing on February 15, 1974, focusing on these industries. As a result of information presented at the hearing, OSHA instituted an emergency temporary standard April 5, 1974, setting 50 ppm as the ceiling value permitted for exposure among workers. Subsequently, the results of animal studies showed that vinyl chloride at 50 ppm induced the same type of cancer found in the workers who had died. This cancer, known as angiosarcoma of the liver, has since been induced in three distinct animal species: rats, mice, and hamsters.

Evidence of the potent carcinogenicity of VC in these animals has been interpreted as foreboding similar consequences to workers who are occupationally exposed to this substance. To date, 24 (19?) deaths from liver angiosarcoma have been found among workers. These deaths may be attributable to high vinyl chloride exposures which were said to exist during the early days of VC production, when the hazards of [illegible] discovered in the past decade — have many really confirmed

not see true and the linear proportion model ... low exposure would ... latency period beyond life expectancy

VC were felt to be virtually non-existent. However, liver angiosarcoma is believed to have a latency period of 20 years, similar to that of other occupational cancers. Thus the long latency period has raised serious doubts as to the safety of any non-negligible level of exposure. In view of the large area of uncertainty regarding VC carcinogenicity, it seems prudent to reduce worker exposure to the minimum levels that can be feasibly attained.

1. DESCRIPTION OF ACTION

In keeping with the legislative intent of the Occupational Safety and Health Act, OSHA proceeded to develop a permanent standard dealing with vinyl chloride that adequately assures, to the extent feasible, that no employee will suffer material impairment of health or functional capacity even if such employee has regular exposure to the hazard for the period of his working life. A proposed standard was published on May 10, 1974, (See Appendix B). The proposed standard reduces the permissible concentration to no detectable level, as determined by a sampling and analytical method capable of detecting vinyl chloride at concentrations of 1 ppm with an accuracy of 1 ppm $\pm$ 50 percent. In addition, the proposed standard requires monitoring of areas defined to have potential occurrence of vinyl chloride to assure that these levels do not go above 1 ppm. In

the event that employees are exposed to higher concentrations, the employer is required to initiate engineering methods and work practices designed to bring the level below 1 ppm. However, if these procedures prove inadequate, the employer must provide protective respiratory devices to employees for their use.

The proposed standard also contains provisions to deal with special problems associated with the maintenance and decontamination of equipment, loading and unloading vinyl chloride, and emergency conditions. Since the health effects of exposure to vinyl chloride are not immediate, but probably involve a long latency period, the employer is required to perform medical surveillance of employees to detect the first signs of liver dysfunction. In addition, the proposed standard deals with the disposition of waste materials, the availability of protective clothing, hygiene facilities and practices, signs and labels, and reports and records.

2. PROBABLE IMPACT

The primary impact of the final OSHA standard will be a reduction of worker exposure to vinyl chloride. According to animal studies, it is probable that attainment of exposures substantially lower than the 50 ppm specified by the emergency standard will constitute a far lower risk than that which

existed prior to the recognition of vinyl chloride as a carcinogen. It is difficult to translate this reduction in terms of human lives: in view of the long latency period associated with vinyl chloride carcinogenicity, the effect of past exposures may not yet have run its course. To date, 24 workers are known to have died from liver angiosarcoma. Others may have died from cancers caused by vinyl chloride but not yet definitively linked to this substance. It is conceivable that such cases in the future are likely to be avoided by implementation of the stricter controls of the final standard.

The impact of the OSHA proposal on industry will be significant. It has been estimated that approximately 75 percent of the capital costs that the OSHA proposal may require will be borne by polymer manufacturers, and much of the remainder by monomer producers.

The effect on individual compounding and fabricating firms is not likely to be as significant as in the case of monomer and polymer producers. Operating costs in the polymer plants will increase substantially according to industry spokesmen.

Additional costs in this industry will arise primarily from increased manpower and energy requirements and decreased productivity. Overall, the OSHA proposal will cause disruptions in the PVC industry during the time that engineering controls are installed and workpractices are evolved.

The net effect of these increased costs will probably be substantial increases in the price of polyvinyl chloride resins, which will ultimately be passed to consumers. Some industry sources have alleged that the price of resins may double within the next few years as a result of the proposed standard. Despite significant cost increases that may occur, the high demand for PVC resins is likely to continue. The superiority of PVC resins to any known substitutes and the degree to which most PVC users are committed to this material imply that a shift to substitutes is not likely to be rapid.

3. ALTERNATIVES

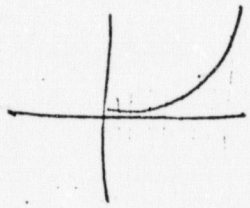
The primary alternatives to the OSHA proposal are: (1) covering only monomer and polymer producers rather than compounding and fabricating operations as well; (2) establishing a permissible level of exposure higher than no detectable level up to 50 ppm; (3) utilizing a staging schedule for implementation; and (4) banning the use of vinyl chloride altogether.

The first alternative, by excluding compounding and fabricating operations from coverage under the standard, would eliminate most companies and most workers covered by the proposal from the scope of the standard. The exposure levels in most compounding and fabricating co[illegible]are probably less than 1 ppm TWA, hence their exclusion from regulation has been proposed by industry. However, evidence was presented at the OSHA hearing of June 25, 1974, that many individual companies or operations may experience temporary excursions greater than 1 ppm.

Since relatively small expenditures should be required to ascertain current exposure levels in these plants, the risk of allowing unacceptable levels in these plants overbalances the attendant costs. Moreover, companies in this category which find exposure levels slightly greater than the permissible level would incur a relatively minor expense for ventilating equipment to reduce exposures within the requirement of the standard.

Needs the purpose but not work practices

The second alternative permitting higher levels of exposure implies a higher expected incidence of angiosarcoma and other cancers. While it is not possible to quantify the expected incidence with any precision, the dose-response relationship computed by the American Cancer Institute from results of animal studies indicates that incidence increases exponentially as exposure levels rise.



understates burden
the PPS would impose on the fabrication

The third alternative would require achievement of exposure levels of 1 ppm TWA on a staging schedule that takes into account the technological problems involved. Most monomer and polymer producers are not able to achieve these levels in the near future, consequently, employees at these plants would be required to wear respiratory equipment for long continuous periods. Wearing respirators continuously in itself can constitute an unsafe situation.

A complete ban of vinyl chloride is likely to cause substantial economic upheaval.

II. BACKGROUND

On January 22, 1974, the B. F. Goodrich Chemical Company informed the National Institute for Occupational Safety and Health (NIOSH) that four employees who worked at its Louisville, Kentucky plant died from angiosarcoma, a rare form of liver cancer. It was suggested that these deaths may have resulted from occupational exposure to vinyl chloride. NIOSH conveyed this information to the Occupational Safety and Health Administration (OSHA), U.S. Department of Labor. On January 24, 1974, representatives from OSHA, NIOSH, and the Department of Labor of the State of Kentucky conducted a walk-through survey of the Goodrich Louisville plant. On January 31, 1974, NIOSH recommended certain monitoring and control procedures to Goodrich and to the Manufacturing Chemists Association for dissemination to other firms engaged in the polymerization of vinyl chloride.

On January 30, 1974, OSHA published a notice in the Federal Register (39 FR 3874) announcing a fact-finding hearing to be held on February 15, 1974 and requesting information on hazards possibly associated with the manufacture and use of vinyl chloride. Information was requested on the following items:

(1) The toxicity of vinyl chloride;

(2) The toxicity of other chemicals involved in the manufacture and use of vinyl chloride;

(11)

(3) The technologies involved in the production and use of vinyl chloride;

(4) Employee populations potentially or actually exposed to vinyl chloride or other chemicals, and involved in the production and/or use of vinyl chloride;

(5) Epidemiologic studies of the effects of vinyl chloride and of other chemicals used in the manufacture or use of vinyl chloride on populations, employee or otherwise; and

(6) Whether the available information would warrant the issuance of an emergency temporary standard or the commencement of a regular rulemaking under section 6(b) of the Occupational Safety and Health Act.

Evidence presented at the fact-finding hearing and through post-hearing comments included the following observations pertinent to determining the need for an emergency or regular standard:

(1) Exposure of laboratory animals to VC by inhalation for durations approximating those of industrial workers at or below the original OSHA standard of 500 parts per million (ppm) (29 CFR 1910.93) induced tumors, including angiosarcomas of the liver;

(2) Tumors were observed in groups of animals exposed to VC at concentrations as low as 250 ppm, but not at concentrations of 50 ppm. Further, the data indicate that a decrease in the number of tumors appears to be related to decreases in the concentration down to the 250 ppm level;

(3) Autopsies of four deceased employees revealed that liver angiosarcoma tumors were histologically similar to those observed in experimental animals.

During the hearing of February 15, 1974, the Industrial Union Department, AFL-CIO, and the United Rubber Workers International Union jointly petitioned for an emergency temporary standard for VC. The Oil, Chemical and Atomic Workers International Union later joined in this petition. On March 14, 1974, in a telegram to the Assistant Secretary of Labor, the President of the United Rubber Workers International Union also urged that an emergency temporary standard be established.

Supporting the necessity for an emergency temporary standard was the fact that workers continued to be exposed to levels far in excess of 50 ppm. Many employers producing vinyl chloride or polyvinyl chloride were complying with the interim controls recommended by NIOSH on January 31, 1974. However, a survey of several manufacturing facilities by the staff of the Office of Standards Development, OSHA, revealed vinyl chloride concentrations as high as 229 ppm for some job classifications.

In light of these facts, an emergency temporary standard

was deemed necessary to provide adequate protection to employees exposed to VC.

On April 5, 1974, an emergency temporary standard for exposure to vinyl chloride was published in the Federal Register (39 FR 12342) and is reproduced as Appendix A to this report. Its essential provisions covered the following three areas:

(1) No employee was to be exposed to vinyl chloride at a concentration in excess of 50 ppm in any operation where VC is manufactured or used. The covered operations included the production and use of VC polymers and copolymers, except in the form of fabricated products (that is, products useful in themselves) or semi-finished products (such as film, sheet, block, bar, or extrusion stock).

(2) The covered operations were to be periodically monitored to confirm that the employees concerned would not be exposed to concentrations in excess of 50 ppm.

(3) If monitoring showed a sample in excess of 50 ppm and for operations where concentrations greater than 50 ppm were likely, employees were to be required to use air supplied respirators or self-contained breathing apparatus.

On May 10, 1974, a proposed standard was published (Appendix B). This proposed standard has been identified as an action requiring an environmental impact statement in accordance with the regulations prescribed under "Procedure for the Preparation and Circulation of Environmental Impact Statements" (29 CFR 1999). On June 12, 1974, the draft environmental impact statement on vinyl chloride was published. Based on information available at that time, it assessed the impact that was expected to result from implementing the proposed standard. Comments on that statement were solicited from industry, labor, government, and other interested parties. Beginning on June 25, 1974, OSHA conducted a public hearing to obtain comments from interested parties on the proposed standard. Participants at that hearing were informed that their comments would also serve as comments on the draft environmental impact statement. Some parties made separate comments on the draft statement; these are reproduced as Appendix C to this report.

This report presents the expected environmental impact of the standard proposed by OSHA on May 10, 1974. It has attempted to incorporate all pertinent comments, opinions, and information which have been presented.

III. HAZARDS OF VINYL CHLORIDE

Vinyl chloride (chloroethene), Chemical Abstracts Service Registry No. 75015, previously had an OSHA standard of 500 ppm because its known toxic effects were thought to be relatively insignificant. Studies reported during the 1960's provided evidence of additional health hazards, prompting the American Conference of Governmental Industrial Hygienists (ACGIH) in 1971 to reduce the threshold limit value (TLV) from 500 ppm ceiling to 200 ppm time-weighted average. As a result of reports of liver cancer deaths among employees at the B. F. Goodrich Chemical Company, OSHA issued an emergency temporary standard of 50 ppm ceiling on April 5, 1974. To date, 24 cases of angiosarcoma have been reported among vinyl chloride workers, including 15 in the United States.

1. SAFETY HAZARDS

Vinyl chloride (VC) is a flammable gas with a boiling point of approximately - 14°C. It has been used as a refrigerant and as an extraction solvent for heat-sensitive substances because of its high vapor pressure. However, the substance's high flammability, acute toxicity, and readiness to polymerize made these uses undesirable. Handling of vinyl chloride presents a substantial hazard, since it is normally gaseous at room temperature and can form explosive mixtures with air. The lower explosive limit is 3.6 percent by volume in air (36,000 ppm); the upper explosive limit is 26.4 percent by volume in air (264,000 ppm). VC is normally stored or transported in liquid form under

ref p.1

pressure, with safety blow-off valves usually provided as a precautionary measure to guard against pressure buildup.

2. ACUTE EFFECTS AND TOXICITY OF VINYL CHLORIDE[2,3,4,5]

Most early studies involving acute exposure to vinyl chloride focused on its narcotic and anesthetic characteristics. In the 1930's, vinyl chloride was considered suitable for supplementary narcosis because of its slight toxicity, wide range of effect, low concentration in the blood stream, and rapid elimination. Several animal studies were conducted to determine appropriate narcotic concentrations. The range for anesthetic effect in animals, generally between 7 and 10 percent by volume in air, is also assumed valid for humans. Dangerous effects appear above 12 percent, and fatalities occur in test animals at concentrations between 20 and 40 percent by volume in air.

Tests on human subjects at concentrations at and below 2 percent by volume in air (20,000 ppm) revealed symptoms such as dizziness, lightheadedness, nausea, dulling of vision and hearing, and headaches which often persisted for short periods of time. Recovery from these symptoms was rapid under test conditions. The gas does not provide adequate warning of its presence by any odor or irritant action. It does, however, produce symptoms of dizziness and disorientation in advance of harmful effects, except when it is present in exceedingly high concentrations.

Two fatalities from vinyl chloride poisoning were reported in the literature.

Few pathologic and histologic studies were performed in the early experiments dealing with acute exposure to VC. In fact, these studies seem to have been somewhat perfunctory. Subsequent investigations established definite evidence of cardiac irregularities, such as sinus arrhythmia (the gradual waxing and waning of the pulse rate), tachycardia (excessively fast heart beat), and bradycardia (abnormally slow heart beat). These particular results seem to have led to the conclusion that VC is unsuitable for narcosis and anesthesia in man. Later studies on animals showed evidence of pulmonary congestion and congestion of the liver and kidneys after short periods of exposure to VC. Studies involving longer exposures (3-6 months) validated the previous studies, showing some evidence of pneumonia, lung lesions, increases in liver to body weight ratios, decreases in spleen to body weight ratios, and mixed changes in kidney weight.[5]

These studies marked the end of research into the acute effects of VC and the beginning of research into chronic effects.

3. CHRONIC AND LONG TERM EFFECTS OF EXPOSURE TO VINYL CHLORIDE

Fifteen years ago, little was known or suspected about either the chronic or the long-term effects of exposure to vinyl chloride. Since that time, VC has come under steadily increasing scrutiny

as evidence of its deleterious health effects mounted. Research efforts of this period can be divided into three areas: (1) those brought about by the persistent appearance of an effect on liver function and involving the examination of the substance's chronic effect on liver function; (2) those delving into the nature and etiology of acroosteolysis; and (3) those involved with the carcinogenic potential of vinyl chloride.

(1) Chronic Toxicity from Exposure to Vinyl Chloride[6,7,8]

The acute toxicity studies of exposure to vinyl chloride repeatedly gave evidence of an effect on liver function, but the brevity of exposure and apparent reversibility of damage precluded attaching much significance to these results. When an investigation was finally conducted to determine the effect of longer-term exposure at lower concentrations, micropathologic changes and increased liver weight were clearly identified in several animal species. In a study[8] designed primarily to indicate the value of a technique correlating clinical and environmental measurements, statistically significant alterations were found in clinical liver tests using measurements of beta-protein, bromsulphalein, and the icterus index among workers exposed for several years to vinyl chloride.

These animal and human studies were not accorded much importance, because of the belief that liver functions would return to normal when exposure to VC ceased. Reports of diseases of the liver, skin, and other organs and studies of hypertension,

vascular lesions, nervous system injuries, kidney damage, and scleroderma (hardening of the skin) were similarly given little weight. More recently, evidence[6] of lung changes and neurologic damage has come to light. When vinyl chloride was implicated as a cause of liver angiosarcoma, several clinical studies were initiated to determine the presence of pathologic abnormalities among workers. One study [20] made a comprehensive examination of workers in a polyvinyl chloride plant which had been in operation since 1946. The results of this study provided some evidence of peripheral vascular disease, enlargement of the liver and spleen, increase of alkaline phosphatase levels, and pulmonary disease. So far, the only significance that can be attached to these results is that evidence of liver dysfunction may have represented the first stages of angiosarcoma. Further clinical studies are required before the full significance of such abnormalities can be appraised.

(2) Acroosteolysis[6,9,10,11,12,13,14,15]

In the middle 1960's, reports emerged of a disease which appeared among workers involved in the polymerization of vinyl chloride. This disease, the "hand problem" or occupational acroosteolysis, is marked by soreness and tenderness of the fingertips. In some cases, it is accompanied by Raynaud's phenomenon (blanching and numbness of the fingers) and by skin lesions. In most cases no symptomatic complaints were registered; presence of the disease was found only through X-ray examinations

of the hands, which indicated osteolysis of the fingers (i.e. the destruction of bony tissues).

As a result of these initial findings, an extensive epidemiologic, industrial hygiene, and clinical study of occupational acroosteolysis was performed in the late 1960's.[12,13,14] Since the disease had been found only among workers engaged in various phases of vinyl chloride and polyvinyl chloride manufacturing, the study focused only on these industries with the purpose of identifying the loci of the disease. This study found that workers who developed acroosteolysis had been involved at one time or another in manually cleaning reactors used in polymerization. The study also suggested that unreacted vinyl chloride was the cause of the disease, although the precise etiology could not be delineated. Generally, it was found that the incidence of acroosteolysis was substantially reduced by the introduction of more automated cleaning of the reactors.

In a later study of acroosteolysis, a more detailed examination of workers was undertaken.[15] Although soreness and cold sensitivity in the fingers were generally the only symptoms identified in the earlier clinical studies, the workers involved in this study also indicated general complaints of excessive tiredness, forgetfulness and slowing down, dizziness, nausea, increased perspiration and upper abdominal pain. Studies of X-ray results were consistent with the earlier findings. Detailed internal

examinations showed many abnormalities, including light to serious thrombocytopenia (small number of platelets in the circulating blood); enlargement of the spleen; toxic liver damage; ventilation blockage; circulatory obstruction; and skin and bone alteration. Although these symptoms have not yet been assigned to a known syndrome nor have their pathogeneses been elaborated, the evidence at this point strongly indicates that vinyl chloride is the etiologic agent.

(3) Carcinogenicity of Vinyl Chloride [6,9,16,17,18,19,21]

Evidence that vinyl chloride has a carcinogenic effect first arose from a study designed to examine more fully the nature of acroosteolysis. The first observations of tumors were reported by Viola in 1970. He exposed Wistar rats to 3 percent (30,000 ppm) concentrations of vinyl chloride for a period of 12 months.[17] In these experiments, skin, lung, and bone tumors were observed. While these results were statistically valid, they were not viewed with alarm, since the concentration of VC was near the explosive limit and was not likely to be found in industrial situations. Nonetheless, Viola's results did indicate the need for an extensive investigation into the type and degree of VC's carcinogenic potential, with special attention to experimental conditions.

On January 22, 1974, the National Institute for Occupational Safety and Health (NIOSH) was informed of three deaths from liver angiosarcoma among workers at the B. F. Goodrich Company in

Louisville, Kentucky. Since then, a total of 18 cases of liver angiosarcoma among PVC production workers and one case among VC monomer production workers have been identified Thirteen of these cases occurred in the United States: seven at the B. F. Goodrich plant in Louisville, Kentucky; three at the Goodyear plant in Niagara Falls, New York; two at the Union Carbide plant in South Charleston, West Virginia; and one at the Firestone plant in Pottstown, Pennsylvania. In addition, three other cases of angiosarcoma have been identified as possibly resulting from vinyl chloride exposure: two workers in PVC fabricating plants and a person who lived within two miles of a fabricating plant developed angiosarcomas. The significance of these last three cases is still somewhat in doubt.

1. Results in Animal Studies

Subsequent to Viola's work, studies by Cesare Maltoni and by the Industrial BIO-TEST Laboratories were initiated to define more completely the carcinogenic hazards of vinyl chloride. At OSHA's public hearing on February 15, 1974, Maltoni[19] indicated that liver angiosarcoma had been observed in Sprague-Dawley rats exposed to VC concentrations as low as 250 ppm. On April 15, 1974, OSHA was informed that BIO-TEST had observed two cases of angiosarcoma in mice exposed to 50 ppm. In testimony[22,23] presented at the public hearing on June 25, 1974, further results from Maltoni showed angiosarcoma at 50 ppm in rats.Later results from BIO-TEST revealed angiosarcoma in hamsters. In all these animals, the following types of tumors were observed: Zymbal

gland carcinomas, liver angiosarcomas and angiomas, kidney nephroblastomas, skin carcinomas, intra-abdominal angiosarcoma, subcutaneous angiopericitoma, pulmonary tumors, mammary carcinomas, and liver fibroangiomas. The angiosarcoma observed in the test animals was of the same morphological type as that observed in the B. F. Goodrich workers. This provided the first clear evidence that vinyl chloride was probably the etiologic cause of liver angiosarcomas among vinyl chloride workers.

Having established the causative effect of VC, the next stage of the animal studies involved determining the dose-response relationship between vinyl chloride and liver angiosarcoma and the appearance of other tumors. The results of one of Maltoni's experiments revealed the following incidence of angiosarcoma in Sprague-Dawley rats following 52 weeks of exposure and 135 weeks of observation:

Dose (ppm)	Angiosarcomas Positive/Total
0	0/68
50	1/64
250	4/67
2,500	13/74
6,000	14/72
10,000	9/69

These results can be fitted to several models to determine risk level (the level of exposure that would be expected to induce one case) and response rate (the number of cases that would be expected at a particular level of exposure). The use of the

probit and logit models, based on different mathematical representations of the data, was demonstrated at the public hearing of June 25, 1974.[24] At their present stage of development, however, they are only hypotheses as to the form of the actual dose-response relationship. The selection of a "most appropriate" model or discovery of a scientifically verifiable safe level must await experimental verification. The results of the applications are given in Tables 1 and 2. Table 1 (risk levels) shows the level of exposure to vinyl chloride in parts per billion (ppb) that would induce liver angiosarcoma in Sprague-Dawley rats at the indicated risk level. Thus, for example, the first entry in the top line indicates that at an exposure of 225 ppb, 1 rat in 100,000 exposed would be expected to contract liver angiosarcoma. Table 2 (response rates) shows the probability that a single Sprague-Dawley rat would exhibit liver angiosarcoma at a given dose level. Thus, the first entry in the top line shows that 0.028 or 2.8 percent of rats exposed to 50 ppm would be expected to contract liver angiosarcoma. The table includes levels below those at which animal experiments have hertofore been performed, such as 25, 10 and 1ppm.

The results of these studies have only slightly advanced the understanding of the carcinogenicity of vinyl chloride. They highlight the many unknowns that need to be clarified before a definitive extrapolation to humans can be made. The results to date, along with the human experience, suggest the existence of a long latency period. In fact, they indicate the possibility

TABLE 1

Extrapolated 'Safe' Dose Level (ppb) Using Maltoni's Liver Angiosarcoma Data*
(99% Assurance Level)

	Risk Level			
Extrapolation Model	10^{-5}	10^{-6}	10^{-7}	10^{-8}
Probit (Slope = 1, Mantel-Bryan)	225	73	26	10
Logit (Slope = 3.454)	553	119	26	5.5
Logit (Slope = 2.303) and "One-hit"	21	2.1	0.21	0.021

* Only the data up through dose level 500 ppm, but not higher, were used since the response curve flattened out at higher levels.

TABLE 2

Estimated Response Rates: Liver Angiosarcoma
(99% Upper Confidence Limit)

	Dose (ppm)			
Model	50	25	10	1
Probit (Slope = 1)	0.028	0.013	0.0044	0.00015
Logit (Slope = 3.454)	0.0085	0.003	0.0008	0.00002
Logit (Slope = 2.303) and "One-hit"	0.02	0.0071	0.0018	0.00006

that, at low dosage levels, the onset of cancer may not occur during the average lifespan of humans. Many of the experimental animals did not exhibit angiosarcoma until late in their lives, and many died, not as a result of the angiosarcoma, but from other causes. Further, the results of these studies suggest that differences between species have an effect upon the incidence of angiosarcoma. This however does not mean that man is necessarily less sensitive than the animals tested. A conservative view is that man is probably at least as sensitive as the rat. Although the rat has a shorter lifespan than man, the rat's metabolic rate is more rapid than man's--thus it could be construed that the rat exhibits a proportionally accelerated version of the possible response in man. These studies also demonstrate that different organs and sites in the body are susceptible to vinyl chloride carcinogenesis at different rates, with the possibility that the angiosarcoma may not actually be the most significant effect. The relative importance of vinyl chloride's various effects still needs to be adequately delineated.

Another area which demands further study is the effect of vinyl chloride on unborn children. In Maltoni's experiments, two subcutaneous fibrosing angiosarcomas were observed in offspring of Sprague-Dawley rats exposed to 6,000 and 10,000 ppm. The significance of these findings is as yet unclear. However, this result does indicate that vinyl chloride appears to have a parent-teratogenic effect, a phenomenon which is common to other carcinogens. Further study into this problem is clearly required to determine

whether additional precautions should be taken to protect pregnant women from exposure to vinyl chloride.

In regard to the mechanism of vinyl chloride once it enters the body, it has been suggested that VC is not the ultimate carcinogen.[25] Preliminary results from an ongoing study indicate that up to a level of approximately 200 ppm vinyl chloride is metabolized by alcohol dehydrogenase. Above this level, it is apparently metabolized by microsomal oxidases. It has been suggested that metabolism through the microsomal oxidases route may produce the ultimate carcinogen. However, since this action can occur at levels below 200 ppm, this does not preclude the possibility that VC is carcinogenic at low doses.

2. Exposure Level for Humans

The most definitive way to establish a "safe" dose level for humans is to examine the data on past exposures and relate it to the occurrence of angiosarcoma. However, data is not available, and the available evidence on the possible effects of exposure can be consideredas only tentative and preliminary.

In view of the relative scarcity of angiosarcoma in the U.S. population, the relationship of the cases identified to date and vinyl chloride exposure shown in Table 3 presents strong evidence that VC is a human carcinogen. This data also shows that the time lapse from the initial VC exposure to diagnosis of angiosarcoma ranged from 11 to 36 years, with an average of 21 years, suggesting the existence of a latency period for the cancer.

TABLE 3

CONFIRMED CASES OF LIVER ANGIOSARCOMA AMONG WORKERS EXPOSED TO VINYL CHLORIDE OR POLYVINYL CHLORIDE

COUNTRY	CASE #	BIRTH DATE	1st VC or PVC EXPOSURE	DX ANGIO-SARCOMA	AGE AT DX	YRS 1st EXP TO DX	TOT YRS EXP	DATE OF DEATH
			VC MONOMER PRODUCTION WORKERS					
Sweden	02	11-27-11	00-00-45	05-15-72	61	27	23	08-16-72
			POLYMERIZATION WORKERS					
United States	01	00-00-22	12-09-48	03-00-71	49	22	16	03-03-73
United States	02	00-00-34	11-15-55	05-00-70	36	14	13	09-28-71
United States	03	00-00-15	11-28-45	12-00-73	58	28	28	12-19-73
United States	04	00-00-24	07-06-52	08-00-67	43	15	15	01-07-68
United States	05	00-00-12	06-19-44	04-00-64	52	20	18	04-09-64
United States	06	00-00-29	01-17-62	02-00-74	45	12	12	ALIVE
United States	07	05-03-22	08-00-44	00-00-68	45	24	18	03-23-68
United States	08	05-06-20	10-07-46	08-00-61	41	15	15	08-29-61
United States	09	00-00-31	05-28-45	03-01-74	43	29	17	ALIVE
United States	10	08-16-13	06-00-51	05-00-68	55	17	17	05-10-68
United States	11	05-27-09	10-14-46	03-00-70	61	23	23	03-16-70
United States	12	11-17-18	09-13-49	05-00-69	50	20	15	05-02-69
United States	13	12-01-21	08-19-44	05-00-74	53	30	30	ALIVE
W. Germany	01	07-26-31	10-14-57	00-00-71	40	14	14	12-14-71
W. Germany	02	06-04-30	10-01-57	00-00-69	39	11	11	01-25-69
Great Britain	01	00-00-01	00-00-46	12-00-72	71	26	20	12-00-72
Norway	01	12-23-15	03-00-50	12-20-71	56	22	21	01-04-72
Sweden	01	06-23-27	08-14-51	02-00-70	43	19	18	10-20-70
			SECONDARY MANUFACTURING					
United States	14	00-00-13	08-18-38	06-00-73	60	36	00	07-03-73
United States	15	00-00-25	00-00-00	07-00-72	47	00	00	02-15-73

Note: '00' indicates unknown date
DX = Diagnosed

The exact exposure levels of VC experienced by the workers who were stricken with angiosarcoma are not known. However, evidence presented at the public hearing

indicated that, at least for the U.S. cases, exposures during the 1940's and 1950's were estimated by industry to be extremely high, frequently over 1000 ppm and commonly in the 100 ppm range. This would seem to indicate that VC carcinogenicity for humans might only occur as a result of high exposure levels. On the other hand, two cases of angiosarcoma that occured in U.S. workers conflict with this hypothesis. One worker was first exposed in 1962 and since that time worked in areas where the exposure levels averaged below 200 ppm TWA. The other case worked in an extruding operation and was probably never exposed to a level above 50 ppm (with TWA's much lower). These two cases cast doubt on the existence of a "safe" level for humans.

At this time, a major epidemiologic study of the relationship between VC levels and carcinogenicity is the Tabershow/Cooper study[26] of 8384 vinyl chloride workers employed in 35 domestic VCM and PVC plants. Workers, employed for at least one year in a job involving vinyl chloride exposure, were subjectively classified according to an index representing their relative exposure level. Results were analyzed for the overall study population according to the estimated levels of exposure, the durations of exposed employment, and the values of the exposure index.

The primary finding of the study was that those exposed to vinyl chloride did not suffer a statistically significant mortality rate increase over what would be expected in a comparable U.S. male population. Other important findings were that cancers of the liver (primarily angiosarcoma), the respiratory system, the brain, the lymphatic system, and unknown primary sites occurred most frequently in those members of the study population who suffered the greatest exposure. Even though these excesses were not statistically significant, the findings warranted further study.

The results of this epidemiologic study do not definitively establish the case for or against VC carcinogenicity. The tentative conclusion of an increased number of malignant neoplasms with VC exposures raises the possibility that vinyl chloride has a more wide-ranging effect than liver angiosarcoma alone.

Further study and analysis of this data seem warranted, such as by the further development of worker histories and by the analysis of each plant by exposure levels, months of employee exposure, length of time since exposures cease, and ages of the workers. Such an investigation might include the development of a population of chemical workers with which to compare the subset of vinyl chloride workers. In addition, an epidemiologic study of workers from compounding and fabricating plants might be useful.

In viewing any epidemiologic data, conclusions drawn have to be tempered by the consideration that the full effects of past exposures among workers may not have yet surfaced because of the latency period associated with VC carcinogenesis. Other unknown factors include the effects of single or intermittent exposures at high or low levels and the effects of small differences in exposure level (such as between 15 and 25 ppm) on the onset of cancer.

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IV. OCCUPATIONAL EXPOSURE TO VINYL CHLORIDE

An assessment of the health hazard from exposure to vinyl chloride must include an estimate of the number of workers exposed, a determination of their past and present exposure levels, and an appraisal of the number of workers who may be expected to contract liver angiosarcoma or other forms of cancer as a result of these exposures. A full characterization of employee exposure to vinyl chloride, however, cannot be accomplished at this point since very little information is available concerning the levels to which workers have been exposed in the past. A reliable model to predict the expected number of cases cannot be formulated because of the lack of data on past exposures and of the mechanism of vinyl chloride carcinogenesis. Consequently, this chapter only attempts to describe the primary potential sources of occupational exposure to vinyl chloride.

Vinyl chloride (VC) is used primarily in the production of polyvinyl chloride (PVC), a thermoplastic resin which has application in a host of products for consumers and industry. The conversion of the VC monomer into a polymer or copolymer is an incomplete process, i.e., not all of the monomer is reacted. Furthermore, despite the fact that the process of stripping removes most of this monomer from the polymer resin, it only partially accomplishes this function. Consequently, residual monomer is usually entrapped in polymer and copolymer formations, and often escapes -- thus posing a workplace hazard in both

PVC and VC plants. The VC content and form of the polymer determine the rate at which VC separates, and the extent of exposure that will occur. Even after the polymer has been fused into a product which will undergo no further heating in bulk (at least to melting temperatures), escape of the vinyl chloride may still occur because of migration to the surface. The OSHA proposed regulation excludes companies using fabricated products since no facts are available to show measurable emissions from fabricated products.

Manufacturing processes involving VC or PVC (containing entrapped monomer) fall into five distinct categories. Figure 1 presents a schematic which shows the interrelationship of these process stages. These are:

- o Production of vinyl chloride monomer;
- o Production of polyvinyl chloride homopolymer or copolymer;
- o Compounding of PVC homopolymers or copolymers with plasticizers, stabilizers, lubricants, fillers, pigments, and other additives;
- o Processing of compounded PVC into finished or semi-finished products; and
- o Fabrication of finished products from intermediate stock.

The fourth stage may yield finished products or semi-finished products used in the fifth stage. Since companies in the fifth stage will not be regulated, this report will examine only the first four stages to estimate the number of workers exposed and

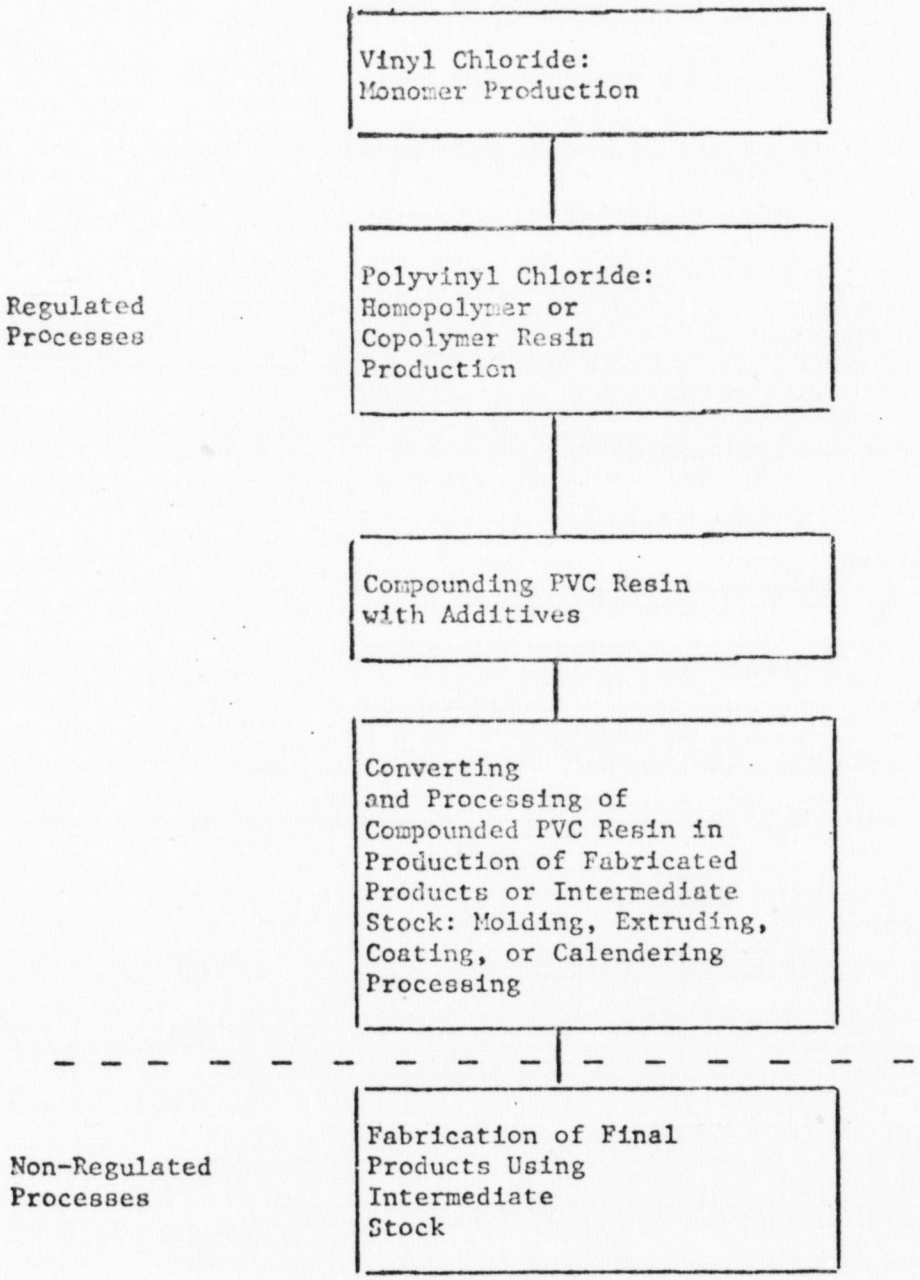


Figure 1. Manufacturing Processes Involving Vinyl Chloride or Polyvinyl Chloride

the level of their exposure to vinyl chloride.

1. PRODUCTION OF VINYL CHLORIDE

Vinyl chloride first attained commercial significance during the 1930's after the discovery that PVC could be processed and converted into a rubber-like product. The ready availability of natural rubber limited development of VC manufacture prior to the outbreak of World War II. When the war cut off supplies of natural rubber, production of vinyl chloride for PVC, as a rubber substitute, was initiated on a large scale. Developments since that time have made vinyl chloride one of the most important starting materials of the plastics industry.

(1) Process Descriptions[1,2,3,5,6,7]

Vinyl chloride is presently produced by 10 companies in 15 plants in the United States (including Puerto Rico), as shown in Table 1. The substance was initially produced by the caustic hydrolysis of ethylene dichloride, subsequently by the pyrolysis of ethylene dichloride to vinyl chloride and hydrogen chloride, and still later by the hydrochlorination of acetylene.[19] Most recently, a newer process involving the oxychlorination of ethylene has become increasingly prominent in VC production, so that presently 13 plants, with almost 92 percent of the capacity, are using the ethylene route.

Hydrochlorination of Acetylene - In this process, also known as the balanced process, vinyl chloride is produced by the hydrochlorination of acetylene, usually with mercuric chloride as the catalyst. A flow diagram for this process is

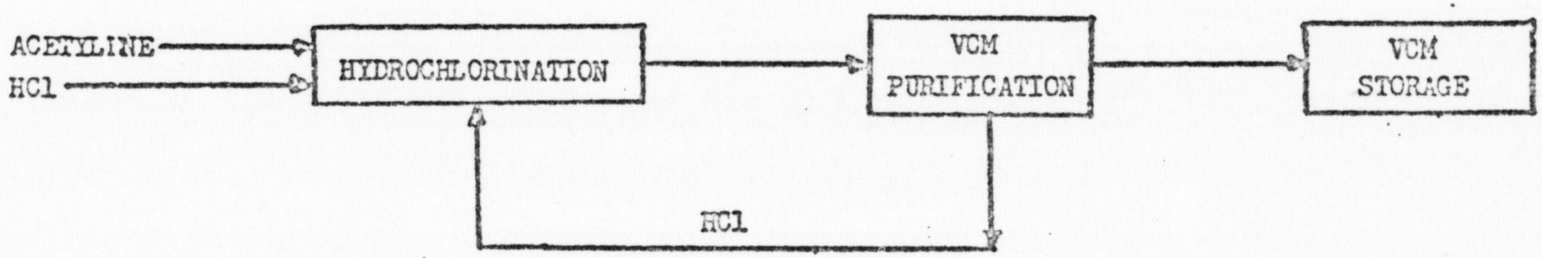
Table 1

Vinyl Chloride Monomer Producers

Company	Location	Nominal Capacity (MM lb.)	Process
Allied Chemical Corporation	Baton Rouge, La.	300	Direct and oxychlorination
American Chemical, Inc.	Watson, Calif.	170	" "
B. F. Goodrich Chemical Company	Calvert City, Ky.	1,000	" "
Continental Oil Company	Lake Charles, La.	625	" "
Dow Chemical Company	Freeport, Texas	180	Direct chlorination
	Oyster Creek, Texas	700	" "
	Plaquemine, La.	340	" "
Ethyl Corporation	Baton Rouge, La.	270	Direct and oxychlorination
	Houston, Texas	150	" "
Monochem, Inc.	Geismar, La.	350	Acetylene
PPG Industries	Lake Charles, La.	300	Direct and oxychlorination
	Guayanilla, P. R.	500	" "
Shell Chemical Co.	Deer Park, Texas	840	" "
	Norco, La.	700	" "
Tenneco Chemicals, Inc.	Houston, Texas	255	Acetylene
		6,680	

Sources: See Bibliography, references 1, 2, 3, 4.

FIGURE 2. MANUFACTURING OF VCM BY DIRECT CHLORINATION OF ACETYLENE



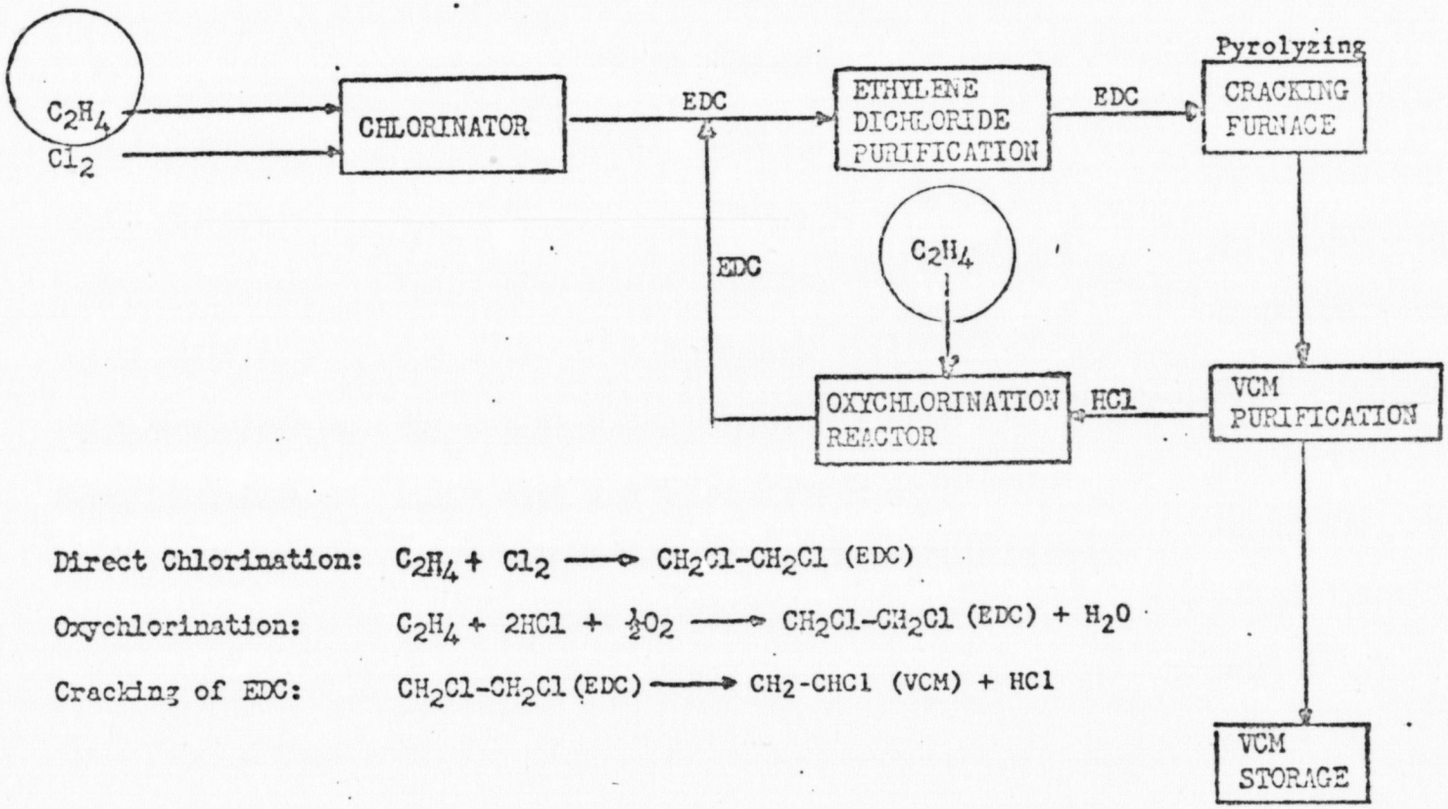
$$CH{\equiv}CH + HCl \longrightarrow CH_2{=}CHCl$$

shown in Figure 2. Acetylene and hydrogen chloride are first passed through a drying tower and then mixed in a chamber packed with activated charcoal. This mixture is passed through several hundred vertical tubes in which the catalyst is packed. The temperature of these tubes is limited to ranges which permit the reaction to take place. The product gases are then fractionally condensed, and the liquid condensate fractionally distilled to obtain vinyl chloride. The VC is finally purified by caustic scrubbing. Most of the variations in this process arise from the use of different catalysts or mixtures of catalysts. Use of this route in the United States has been declining due to the reduced availability of acetylene feedstocks.

Oxychlorination of Ethylene - Ethylene can be directly chlorinated to produce vinyl chloride; however, difficulties with this technique have led to VC production from ethylene through the intermediate formation of 1,2-dichloroethane (also called ethylene dichloride) a process used by several plants in the United States, Japan, and Europe. A schematic of this process is shown in Figure 3. There are several variations of this process which have demonstrated commercial feasibility. Differences among these generally arise in the amount of recycling or in the materials used as catalysts.

The EDC comes from two sources: chlorine combined with ethylene in a liquid phase reaction with a dissolved catalyst

FIGURE 3.. MANUFACTURING OF VCM BY DIRECT CHLORINATION AND OXYCHLORINATION



Direct Chlorination: $C_2H_4 + Cl_2 \longrightarrow CH_2Cl\text{-}CH_2Cl$ (EDC)

Oxychlorination: $C_2H_4 + 2HCl + \frac{1}{2}O_2 \longrightarrow CH_2Cl\text{-}CH_2Cl$ (EDC) $+ H_2O$

Cracking of EDC: $CH_2Cl\text{-}CH_2Cl$ (EDC) $\longrightarrow CH_2\text{-}CHCl$ (VCM) $+ HCl$

VC production is closed process

(in a chlorinator) and ethylene combined with hydrogen chloride and oxygen in a vapor phase reaction with a catalyst (in an oxychlorination reactor). The crude EDC from these two units is then purified by distillation. The final operation involves the thermal cracking (pyrolysis) of this EDC to form vinyl chloride and anhydrous hydrogen chloride. The resulting effluent is then separated by fractionation. The vinyl chloride is stored, the hydrogen chloride is passed back to the oxychlorination unit, and unreacted EDC is recycled.

(2) Worker Exposure[3,8,9,10,11]

Since vinyl chloride is produced in outdoor plants, the build-up of the substance in the workplace is less than that observed during the subsequent process stages involving the monomer or polymer. The job categories of workers at VC production plants are shown in Table 2. No data is currently available showing the number of people nationwide who are employed in each category. At the OSHA hearing on February 15, 1974, the Manufacturing Chemists Association estimated that 1,500 people work in monomer production. However, since monomer plants differ significantly in age, type, and degree of automation, it is not possible to validate this number. For example, PPG Industries states that it employs between two and four workers per million tons of stated capacity. Based on this figure, the number of workers in monomer plants would be estimated at 1,700 to 3,300. However, it is not possible to characterize such plants for the purpose of categorizing workers

Table 2

Job Categories of Workers

Vinyl Chloride Plants

Control Operator	Material Controller
Distillation Operator	Millwright
EDC Operator	OXY Operator
Electrician	Pipefitter
Instrument Technician	Quality Control Specialist
Laboratory Technician	Sample Man
Laborer	Shift Supervisor
Loading Operator	Tank Farm Operator
Maintenance Worker	VCM Operator

according to exposure levels. As a result, exposure data can only be addressed in general terms, until a comprehensive survey of the industry can be conducted.

An estimate of the number of workers in each job classification is necessary for any characterization of the total hazard of vinyl chloride production, since data presented to OSHA has indicated different peak and time-weighted-average concentrations for the various categories. The major sources of exposure under normal conditions are judged to be:

- o Sampling and analysis of vinyl chloride for quality control;
- o Loading of vinyl chloride for shipping;
- o Entry of vinyl chloride containing vessels for maintenance and repair work; and
- o Leaks of vinyl chloride in the process area.

Some sampling data indicate peak concentrations over 200 ppm for laboratory technicians, over 150 ppm for loading operators, and near 50 ppm for quality control specialists. Time-weighted-averages generally fall well below 50 ppm. Since these results were obtained prior to the emergency temporary standard, they possibly do not represent current levels of exposure to vinyl chloride. Thus, this information should be viewed only as indicative of the categories of workers where high exposures to VC may occur.

2. PRODUCTION OF VINYL CHLORIDE POLYMER AND COPOLYMER RESINS

Virtually all vinyl chloride produced in the United States and not exported is used to manufacture either vinyl chloride homopolymers or vinyl chloride copolymerized with such monomers as vinyl acetate, vinylidene chloride, and acrylates. Generically, these homopolymers and copolymers are known as polyvinyl chloride (PVC) resins. They are generally found in the form of powders which, after being compounded with a variety of additives, are processed to produce a large variety of plastic or resinous end products. Table 3 lists the 22 companies and 37 plants in the United States who produce the homopolymer resin, as well as the capacity of each plant.[19] Additional plant openings and the expansion of present plants that are currently planned are estimated to add to the capacity by approximately 2,000 million pounds.[19]

Most commercial resins have molecular weights between 30,000 and 120,000, the weight being a determinant of the resin's processing and performance characteristics. These characteristics are also affected by the specific additives with which the resins are compounded. Since theoretical results do not definitively indicate what mixtures will give rise to what properties, formulation and processing is largely a matter of experience.

Table 3

Vinyl Chloride Polymer and Copolymer Resin Producers

Company	Location	Nameplate Capacity (MM lbs.)
Air Products & Chemicals, Inc.[1,2,3]	Calvert City, Ky.	150
	Pensacola, Fla.	50
American Chemical Corporation[1,3]	Long Beach, Calif.	150
Atlantic Tubing & Rubber Company[3]	Cranston, R.I.	Unk.
B.A.S.F. Wyandote Corporation[3]	South Kearney, N.J.	Unk.
B. F. Goodrich Chemical Company[1,3,4]	Avon Lake, Ohio	140
	Henry, Ill.	140
	Long Beach, Calif.	140
	Louisville, Ky.	340
Borden, Inc.[1,3,4]	Pedricktown, N.J.	170
	Illiopolis, Ill.	140
Continental Oil Company[1]	Leominster, Mass.	180
	Aberdeen, Miss.	285
Diamond Shamrock Corporation[1]	Oklahoma City, Okla.	240
	Delaware City, Del.	100
Dow Chemical[3]	Deer Park, Texas	270
	Midland, Michigan	Unk.
Ethyl Corporation[1]	Baton Rouge, La.	180
Firestone Tire & Rubber Company[1,3]	Perryville, Md.	230
	Pottstown, Pa.	270
General Tire & Rubber Company[1]	Ashtabula, Ohio	125
	Point Pleasant, W. Va.	50
Goodyear Tire & Rubber Company[1]	Niagara Falls, N.Y.	100
	Plaquemine, La.	100
Great American Chemical Corp.[1]	Fitchburg, Mass.	40 — should be "70"
Hooker Chemical Corporation[1,3]	Burlington, N.J.	180
	Hicksville, N.Y.	15
Keysor Century Corporation[1,3]	Saugus, Calif.	35
Monsanto Company[1]	Springfield, Mass.	70
Morton-Norwich Products, Inc.[3]	Ringwood, Ill.	Unk.
National Starch & Chemical Corp.[1,3,4]	Meredosia, Ill.	10
Olin Corporation [1,3]	Assonet, Mass	150
Pantasote Company [1,3]	Passaic, N.J.	60

Table [illegible] (cont'd)

Vinyl Chloride Polymer and Copolymer Resin Producers

Company	Location	Nameplate Capacity (MM lbs.)
Robintech, Inc.[1]	Painsville, Ohio	250
S.C.M. Corporation[3]	Huron, Ohio	Unk.
Stauffer Chemical Company[1]	Delaware City, Del.	175
Tenneco Chemicals, Inc.[1,4]	Burlington, N.J.	165
	Flemington, N.J.	70
Union Carbide Corporation[1,4]	South Charleston, W. Va.	160
	Texas City, Texas	240
Uniroyal, Inc.[1]	Painsville, Ohio	140
W. R. Grace and Company[3]	Owensboro, Ky.	Unk.
	South Acton, Mass.	Unk.

1/ Homopolymer.
2/ Vinyl chloride - propylene.
3/ Vinyl chloride - vinyl acetate copolymer.
4/ Vinyl chloride - vinylidene chloride copolymer.
Sources: See bibliography references 2, 12, 13, 14.

Four basic processes are employed in polymerization or copolymerizations: bulk, suspension, emulsion, and solution. The bulk process is a dry process requiring no water, suspending agents, or emulsifiers. The other three processes require water, solvents, or other liquids, but they are similar enough to use the same equipment, although each plant usually limits itself to only one process. Polymerization of monomers is initiated by free radicals produced by thermal decomposition from peroxides, azo compounds, and persulfates. The rate of polymerization and the molecular weight distribution of the resin are largely determined by the temperature of the reaction and the concentration of initiators. General schematics for the bulk, suspension and emulsion processes are shown in Figures 4 and 5.

(1) Process Descriptions[1,12,13,15]

In the United States, approximately 78 percent of PVC resins is produced by suspension polymerization, 13 percent by emulsion polymerization, 6 percent by bulk polymerization, and 3 percent by the solution method. The bulk polymerization process is relatively new and has been used for an increasing proportion of the production of PVC resins in recent years.

FIGURE 4. MANUFACTURING OF PVC BY BULK POLYMERIZATION

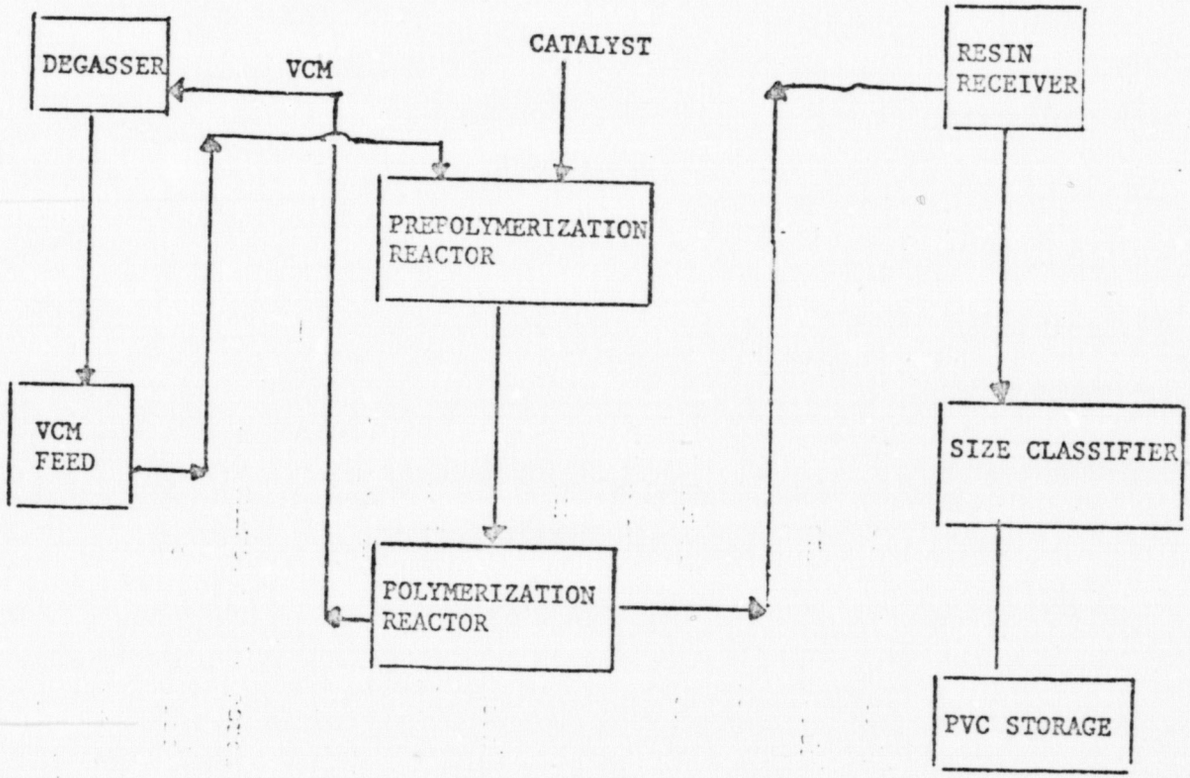
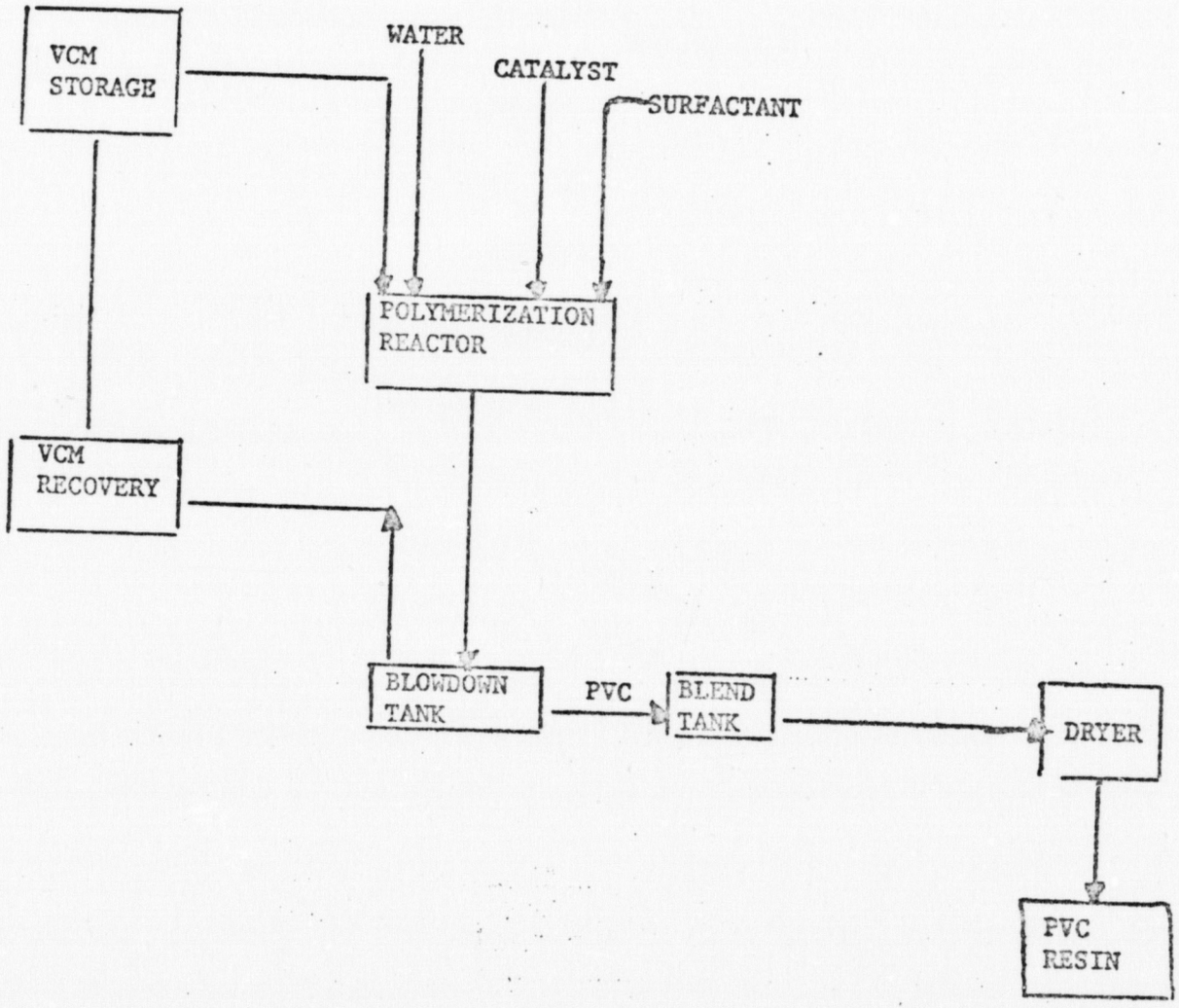


FIGURE 5. MANUFACTURING OF PVC BY SUSPENSION AND EMULSION POLYMERIZATION



Suspension Polymerization - This process is essentially a batch process generally carried out in glass-lined reactors having a capacity of 2,000 to 6,000 U.S. gallons. Monomer soluble initiators, such as lauroyl, decanoyl, and benzoyl peroxides, are dissolved in liquid monomer dispersed in water to form a suspension. The reactor is first charged with the required amount of deionized water. Then the dispersant, a buffer, and the initiator are added. Oxygen is evacuated from the reactor, and the vinyl chloride and any comonomer are fed in. Agitation (to increase the degree of dispersion) is begun, and the contents of the reactor are brought up to the polymerization temperature (45-60°C). After the ten to sixteen hours of the polymerization process, the contents of the reactor (the PVC slurry), are dumped into a large vessel and excess vinyl chloride is recovered for distillation and reuse. The slurry is then blended with other batches in another vessel to reduce small variations and dehydrated by a continuous solid bowl centrifuge to make a polymer cake containing about 20 percent moisture. The polymer is finally dried in a flash dryer; the resulting particles are sorted out by passage through a cyclone separator. The product is then screened and sent to storage.

Emulsion Polymerization - This process is very similar to the suspension process, and is primarily used to produce exceptionally fine particles. There are two primary differences: (1) The suspension process uses mechanical mixing, while the emulsion process uses surfactants and agitation to convert the monomer to a stable emulsion containing very small monomer particles and; (2) In the emulsion process, the polymer is separated from the water by spray drying, which the nature of the polymer necessitates. While this process is more costly, it is important to users who need PVC in liquid form. In addition, this type of polymer has the ability to form a paste when combined with a plasticizer. In some cases, the slurry is not dried, but instead is produced in a latex form.

Bulk Polymerization - In this process, vinyl chloride is polymerized without the addition of other liquids and in the presence of a free-radical initiator. A portion of a day's supply of monomer is initially pumped into a prepolymerizer.

The mixture from the prepolymerizer, together with an equal amount of fresh monomer, is transferred into an autoclave equipped with slowly rotating agitator blades where the reaction is induced by high pressures. The reaction is autocatalytic and accelerates with increasing conversion of the monomer. After the monomer has been converted, unreacted monomer is removed by a vacuum and recovered in a recycle condenser. The resin is transferred to a

resin receiver. Fines are collected in a dust separator and removed through a manhole. The output of bulk processing plants is said to be more than twice that of good suspension plants of comparable size.[12] This factor will probably lead to a greater use of bulk polymerization during the coming years.

Solution Polymerization - This process is used exclusively for the production of copolymers of vinyl chloride and vinyl acetate. The mixed monomers are dissolved in an organic solvent inside a stirred autoclave heated to 40°C. The reaction in the autoclave has the same autocatalytic characteristic as that occurring in bulk polymerization. In this case, however, the phase separation, arising from the formation of a concentrated polymer base, leads to a decrease in the rate of polymerization. The contents of the autoclave are passed through a filter press to retain the polymer, and the filtrate is recycled. The filtered polymer (in the filter press) is then washed, during which a certain amount of unpolymerized vinyl chloride is recovered by fractional distillation.

(2) Worker Exposure [8,9,16]

It has been estimated that the total number of workers engaged in all aspects of the production of PVC resins is about 5,000. The validity of this figure is suspect, however, since an industrial hygiene survey conducted in 1969 examined over 5,000 PVC-related workers at a time when production was approximately half the current level. Only a small proportion of these workers

were engaged in operations outside the actual resin production. The productivity of these workers has probably increased since 1969 in view of some significant technological changes such as the introduction of the bulk polymerization process, but, on balance, the total number of workers has probably increased beyond 5,000, although less than 10,000. Some of the job classifications of workers involved in resin production with potential exposure to VC are shown in Table 4. No evaluation of the total industry exposure to vinyl chloride can be made at present, because no estimates of the personnel distribution in these categories are available for the entire industry, and because exposure varies according to job category.

The information available does tend to indicate that exposure to VC is greater in resin producing plants than in those synthesizing the monomer. The areas of greatest exposure in a PVC plant are judged to be the following:

- Unloading of incoming vinyl chloride;
- Reactor cleaning;
- Entry of vinyl chloride containing vessels for maintenance and repair work;
- Entry of PVC storage silos;
- Shipping or packaging of PVC; and
- Leaks of vinyl chloride in the process area.

Levels of VC exposure in these plants have been decreasing rapidly since January, 1974. For the entire industry, the average TWA is probably well below 25 ppm. Exposures differ

Table 4

Job Categories of Workers

Production of PVC Resins

Bagging and shipping operator	Monomer recovery operator
Catalyst makeup man	Monomer supervisor
Dryer operator	Polymer supervisor
General laborer, custodial	Reactor cleaner
Laboratory technician	Reactor operator
Maintenance personnel	Slurry blender
Monomer maintenance personnel	Utilities operator
Monomer operator	Warehouse personnel

for each job category, but, from the available data, it appears that reactor cleaners are likely to suffer the greatest exposure. Operators of the polymerization process equipment, those involved in unloading or transferring the monomer, and maintenance personnel, respectively, have successively lower exposures to VC. Other personnel are likely to be exposed to considerably lower levels.

Reactor cleaning poses a special hazard. During the reaction process, the polymer, with entrapped monomer, builds up on the surface of the reactor, so that periodic cleaning is usually required. In the past, most of this cleaning was performed by hand using a scraper and chisel. Air analyses have shown that VC concentrations in the reactor prior to ventilation reach 3,000 ppm. After ventilation has been completed and the worker begins the scraping, concentrations between 50 and 100 ppm may easily be released. Air analyses have shown concentrations of 600 to 1,000 ppm of VC close to the hand. Since these studies were completed, industry has moved to greater use of water-jet or organic-solvent cleaning.

Industry has also instituted monitoring procedures of reactor interiors prior to worker entry.

Another exposure problem concerning reactor cleaning has been that the air left in the reactor disperses into workroom air, thus producing a major source of vinyl chloride exposure. Substantial efforts are currently underway to recover all unreacted monomer prior to opening the vessel, but the low levels

involved pose a significant technological difficulty.

3. Compounding of PVC Resins with Additives[1,12,15,17]

In most applications, PVC is used with one or more additives to order to process and convert the compound into its final products. The additives used depend on the initial form of the resin, the type of processing to be used, and the desired application. Resins are classified either as general purpose (made by any of the techniques described in the previous section) or as dispersion (made primarily by emulsion polymerization). After the addition of a plasticizer, the general purpose resins can be further categorized into plasticized resins and unplasticized (i.e. rigid) resins. The dispersion resins, or latexes, may be plasticized for ultimate use as plastisols or organosols, or they may be chlorinated for processing similar to that performed on the general purpose resins.

To these basic resins, additives are compounded according to particular requirements. These additives are usually categorized as follows:

- o Plasticizers, to increase resin flexibility, softness, and elongation, and in some cases, to extend the basic resin;
- o Heat stabilizers, to prevent discoloration during the processing of resin compounds;
- o Fillers, to reduce costs, but sometimes to produce opacity, specific electrical properties, resistance

to ultraviolet light, resistance to blocking, improved dryblending characteristics, and other properties;

- o Pigments and dyes, to color PVC resin compounds;
- o Processing aids, to facilitate the achievement of certain processing objectives, such as increased processing rates, lower processing temperatures, improved fusion, and reduced surface gloss;
- o Impact modifiers to protect rigid resins against brittle fracture;
- o Lubricants, to reduce friction of melts with the surfaces of processing machinery and molds;
- o Light stabilizers, to prevent PVC degradation from continuous exposure to sunlight;
- o Fungicides, to inhibit the vulnerability of compounded PVC to attack by microorganisms;
- o Flame retardants, to preserve the nonflammability of PVC compromised by the use of flammable plasticizers;
- o Antistatic agents, to improve electrical conductivity;
- o Antioxidants, to provide protection in high-temperature applications; and
- o Foaming agents, to influence cell structure for resins expanded into foams.

The compounding of these additives with PVC resins may occur in a plant producing the basic resin, in a plant designed for the purpose of compounding alone, or in a plant which also processes the compounded resins. Trade publications identify

approximately 200 companies supplying chlorinated, plasticized, and rigid PVC or copolymer resins.

The mechanism of the compounding stage ensures that the additives are fully dispersed in the PVC resins to yield a homogeneous material suitable for further processing. The resultant compounds may be in powder or granular form. The latter form is obtained by heating the compound into granules or pellets. These are then used as feedstock for subsequent extrusion and molding processes. The powder form can be fed directly into fabrication equipment where the PVC resin need be heated only once, thus requiring fewer additives.

(1) Process Descriptions

A wide variety of compounding equipment is currently available, most of which uses the resin and the various additives in dry form. Sometimes, the resin is premixed with several additives before it is used in further processing with other additives. The order in which specific compounding equipment is used depends on the specifications the PVC must meet.

Two-Roll Mill - The material in the form of a powder blend is fed into a mill consisting of two rolls separated by a small gap. The mill kneads the material for about 10 minutes at a temperature of 150-160°C and strips it off as a continuous band. This strip of material is then granulated into small cubes suitable for use in an extruder.

Banbury Mixer - The mixer consists of a jacketed mixing chamber fitted with blades rotating in opposite directions. It mixes batches of the material under pressure and heat to produce a fused and kneaded mixture. The mixture then is discharged in a doughlike mass which is converted into sheet form for granulation. A two-roll mill is utilized for this purpose. The use of Banbury mixers can lead to significant variations between batches. This inconsistency is tempered in some cases by the use of automatic weighing and feeding systems for the injection of the various mixing materials.

Continuous Mixers - This type of mixing is designed to enhance the consistency between batches by providing a continuous feed operation; however, this process requires great care to ensure the homogeneity of the resultant mixture. The machines used are basically single or twin-screw extruders, modified to optimize the handling of the material. The compound may be heated, fed directly to calenders, extruded through a die plate for granulation, or extruded through a die with a die-face cutter for granulation.

Multiscrew Compounders - A twin-screw extruder, specially adapted for the purpose, is also suitable for PVC compounding. The primary advantage this equipment offers, as opposed to the extruders described above, is that its screw sections and kneading discs can be changed to meet the specific requirements of the material being compounded.

High-Speed Mixers - Equipment featuring injection molding and extrusion has also been modified to accept PVC powder blends. To ensure satisfactory processing, such blends are combined in a high-speed mixer by friction-generated heat. When this type of equipment is used, the production of the proper blends must be performed with great care.

Wet Granulation - In this process, the PVC is taken directly from the polymerizer while still in an aqueous dispersion. The additives are introduced into the granulating vessel along with a plasticizer that had previously been mixed with some of the stabilizer and lubricants. The compounded resin particles are then rapidly plasticized, producing a substance in the form of granules which are easily separated from the suspension. This process is limited to polymer manufacture, since it is not economically feasible to redisperse the polymer once it has been dried out.

Mixing of Plastisols - PVC pastes can be produced using paddle-type mixers that can be operated under a vacuum, such as the vertical paddle mixer, the vertical planetary mixer, or the horizontal Z-blade mixer. The PVC resin is introduced into the mixer along with sufficient plasticizer to form a paste. Other ingredients are then incorporated slowly and at low temperatures until a smooth homogeneous paste is obtained.

(2) Worker Exposure

In regard to worker exposure during PVC compounding, the PVC resin and the compounds involved in the processing at this stage contain residual amounts of vinyl chloride in concentrations which may be as high as 3,000 ppm. If the basic resin is stored for some time in bags or drums, it will release an amount of the monomer inside the container which could enter the ambient air upon opening the container.

Mixing operations during compounding may allow an additional release of the monomer entrapped in the polymer. Levels in the workroom air are generally below 1 ppm, although evidence presented at the OSHA public hearing of June 25, 1974, shows th excursions above this level are not infrequent. These studies do not conclusively establish one way or the other whether workers engaged in compounding are exposed to concentrations in excess of 1 ppm. Sufficient information is not yet available to enable a categorization of plants into those where concentrations above 1 ppm are likely and those where they are not likely. The highest exposures in this phase probably occur in storage areas, places where containers are opened, and near processing equipment where the PVC is heated.

The numbers and types of workers exposed to vinyl chloride during these compounding operations are not known. Trade publications list about 200 firms, but give no estimate of their sizes.

4. Fabrication of End Products from PVC Compounds[1,12,15]

The usefulness of polyvinyl chloride arises from its adaptability to many processing techniques used in the production of intermediate and final goods. These processes have been designed to accomodate a wide variety of plastic compounds, including PVC because of the its ease in processing and its flexibility in allowing for the manufacture of a wide variety of products. In these processes, PVC resins compounded with the necessary additives are converted into products which need no further chemical handling. The products at this stage may be final goods (such as pipes), components of other equipment (such as wires), or materials for other industries (such as films and sheets for packaging). As a result, products made at this stage may or may not be subjected to further processing, but if so, they will no longer be designated as PVC. The number of firms engaged in this processing stage is not precisely known, but has been estimated to be between 4,000 and 20,000. Such firms range in size from those with few employees and simple equipment to large plants involving many employees and considerable capital.

(1) Process Descriptions

The processing of PVC compounds at this stage involves the shaping of the compound into its desired form. This is accomplished by subjecting it to intense levels of heat and considerable pressure. Several types of equipment are used according to the final product desired. The major processes

used to convert PVC into fabricated products are described below.

Extrusion - Both plasticized and rigid PVC formulations (as powder blends or granules) can be extruded (i.e. forced through a die) into a variety of shapes. Determination of the necessary temperatures and other process characteristics, such as rate at which the extrusion is to be carried out, can only be ascertained by careful experimentation. Extrusion is used primarily to produce wire and cable insulation, rigid pipe and tubing, blown film, and unplasticized PVC sheet.

Injection Molding - Generally, low-molecular-weight PVC resins in the form of granular or powder blends are used in screw-type injection molding machines. The rotation of the screw produces a homogeneous melt which is then injected into a mold at high pressure.

Blow Molding - This process is generally limited to the production of bottles, and primarily uses powder blends with some interspersion of granular compounds. Most of the equipment used in this process produces a parison (i.e. a partially formed mass of material still in plastic form) by continuous extrusion or by the use of a reciprocating-screw system. This parison is then blown into the proper mold.

Compression Molding - This technique is used primarily for processing rigid PVC compounds into phonographic records. Usually, a copolymer of vinyl chloride and vinyl acetate is

used to produce a low-viscosity melt. This melt is mixed and fused, passed to a two-roll mill from which it is stripped, and then molded by compression in a record press at high pressure. The initial compound can also be in pellet form from which a premeasured molten extrudate is pressed in a mold. This technique is also the only method used to manufacture thick, high-quality, rigid sheet.

Calendering - This technique is used extensively for the production of flexible and rigid PVC film and sheeting. It is usually found in conjunction with the mixing of additives rather than as a separate stage in the processing of PVC. Pellets or powder are fed directly to the hot rolls of the calender. The resulting molten material is carried through finishing rolls to produce rigid sheets or material laminated to a substrate.

Plastisol Processing (Coating) - In this process a paste (or plastisol) made from PVC resin compounded with various additives is coated on various substrates such as fabrics, sheet steel, and paper. Several types of equipment may be used to perform the coating. The paste is generally fed into a device which applies the material to the substrate, either once or several times to achieve the desired thickness. The material is then passed through a heating oven to produce complete fusion of the compounded PVC paste material.

Plastisol Processing (Molding Methods) - For molding purposes, several methods may be employed to shape a PVC paste into its desired shape. A measured amount of paste may be charged into a mold. The mold is then rotated to cause the paste to gravitate to the walls where it is fused to form a uniform thickness. The paste may also be poured into a mold where it is fused. Low-pressure injection molding is also used to produce PVC shoe soles.

Foams - Flexible or rigid PVC foams can be produced by subjecting PVC plastisol to mechanical or chemical blowing. In this process, the plastisol is mixed with an inert gas or air which is then fed through spray nozzles under carefully controlled conditions to produce a slowly expanding foam. The plastisol is whisked and the resulting froth is stablized. One of these mixtures is then subjected to heat, while being calendered, extruded or molded, so that it is fused into the desired form.

(2) Worker Exposure

Exposure to vinyl chloride in the fabricating stage arises from the escape of residual monomer entrapped in the polyvinyl chloride. The monomer escapes at its fastest rate when the compound is heated. In general, the rate and the amount released depend on the residual amount, the extent to which the PVC has been diluted by additives, the type of equipment used for processing, and the temperature at which the PVC is processed. Worker exposure depends on the rate and the amount

released, as well as the extent to which the processing area is ventilated. These factors have yet to be definitively delineated for each type of processing, so that it is not possible at this time to state which processes might result in excess exposures.

Information presented at the OSHA public hearing of June 25, 1974, indicated that the concentrations of vinyl chloride in fabricating plants fall generally below 1 ppm with a small number skirting this level. An even smaller number of readings showed concentrations in excess of 1 ppm, ranging as high as 40 or 50 ppm on occasion. However, the information available as yet shows no clear-cut pattern which could permit a full characterization of exposure levels according to process type. In general the numbers and types of workers exposed to vinyl chloride in its fabricating stages cannot be estimated until a scientific sample of the industry is performed.

NOTES

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V. DESCRIPTION OF ACTION

In response to the health hazards of vinyl chloride that have recently become known, the Occupational Safety and Health Administration (OSHA) published a proposed standard in the May 10, 1974, Federal Register (Appendix B).

Public hearings were held beginning June 25, 1974, to obtain information from industry, labor, and other interested parties regarding the provisions of the proposed standard. Information presented at the hearing and in post hearing comments, as well as recently available research data, feasibility studies and this Environmental Impact Statement are being considered in the development of the final standard.

Applicability of Proposed Standard

The proposal would apply to any company manufacturing or using vinyl chloride or polyvinyl chloride (when the latter releases detectable amounts of vinyl chloride). Detectable levels were defined as those measurable by a method capable of detecting 1 ppm with an accuracy of ± 50 percent.

Raw polyvinyl chloride resin and the many compounds made from this resin for molding, calendering, extrusion, or other similar processes were considered to have the potential for releasing detectable levels of vinyl chloride. If the PVC compounded resin contains a large proportion of unreacted monomer, its handling and heating will release some part of that monomer.

Operations handling fabricated products made from polyvinyl chloride, entirely or in parts, were specifically excluded from the standard. The reason was that the release of monomer from such products had not yet been demonstrated. The proposed standard specified that fabricated products would include such items as film, sheet, block, bar, and extrusion stock.

Level of Exposure

The proposed standard for employee exposure to vinyl chloride was set at the no detectable level, to be determined by a sampling and analytical method capable of detecting vinyl chloride at concentrations of 1 ppm with the accuracy of 1 ppm $\pm$ 50 percent. The method of 1 ppm sensitivity was recommended to OSHA by NIOSH on the basis of its review of the problem. The proposal also attempted to minimize the number of workers at risk by regulating areas where vinyl chloride is manufactured, reacted, stored, handled, released, repackaged, or used. Polyvinyl chloride operations containing detectable levels of vinyl chloride were also regulated. The proposal permitted only authorized employees to enter such areas; authorized workers were defined by the proposal as those employees whose duties require them to be in the regulated areas, and those employees who enter such an area as designated worker representatives to exercise their right to observe the monitoring and measuring of vinyl chloride.

Monitoring

A monitoring program was to be required by the proposal to determine if there were detectable levels of vinyl chloride in the workplace and to measure employee exposures on an individual basis. The standard permitted a maximum amount of flexibility for the employer in devising a suitable monitoring system. This was done on account of the diversity of the processing methods involving the monomer, the polymer resin, and the compounded resin. The employer was, however, to be required to monitor in such a way that detectable levels could be perceived and that exposure to an employee could be determined with a confidence level of 95 percent. These programs were to involve the use of point monitoring devices, portable air samplers, or personal samplers worn by employees.

In addition, Section 8(c)(3) of the Occupational Safety and Health Act requires that employees or their designated representatives be provided an opportunity to observe monitoring.

Engineering and Work Practices

If detectable levels of vinyl chloride were present under normal operating conditions, the employer was to be required to immediately institute engineering controls, work practice methods, and respirators in accordance with the proposal. Engineering controls and work practices were considered preferable to other methods of compliance, since they focus on eliminating contamination of the air in the workplace rather than on simply providing a temporary solution.

The proposal also required that tests be conducted for process or equipment leaks to ensure the integrity of the equipment and the propriety of work practices. In the event that these control measures were insufficient to control airborne concentrations of vinyl chloride, immediate use of protective respiratory devices was to be required.

Respiratory Protection

In the event that respiratory protection would be required under normal or emergency situations, the employer would be required to select equipment from among the following types:

- Positive pressure full facepiece self-contained breathing apparatus;
- Pressure-demand full facepiece self-contained apparatus operating in the pressure-demand mode;
- Combination type "C" pressure-demand full facepiece respirator operating in the pressure-demand mode and a pressure-demand self-contained breathing apparatus operating in the pressure-demand mode; or
- Combination type "C" continuous flow respirator and a pressure-demand self-contained breathing apparatus operating in the pressure-demand mode.

Protection against vinyl chloride was not considered reliable from cartridge type respirators due to the short break-through time for vinyl chloride at high concentrations. As a result, NIOSH

recommends the use of continuous flow and pressure-demand types of respirators. Respirators were not to be used instead of feasible engineering controls or work practice methods.

Protection in Special Situations

(1) Maintenance and Decontamination

The proposed standard recognized that VC and PVC operations are frequently conducted in batch processing equipment requiring frequent cleaning to ensure the purity of the process. The proposed standard required special precautions for cleaning operations designed to maintain or decontaminate equipment. Some types of equipment, such as reactors in the polymerization process, were believed to allow significant buildups of vinyl chloride. The proposed standard required adequate venting of such vessels to remove escaping vapor from occupied areas before worker entry. In addition, employers were to provide workers with whole-body, air supplied suits impervious to vinyl chloride. Workers were also to be required to shower after removing such equipment. The proposal emphasized the immediate clean up of spills, periodic inspections, and the prompt repair of equipment and leaks. Provisions also addressed the proper handling, storage, and disposal of materials to prevent airborne contamination and accidental skin contact.

(2) Transporation Loading and Unloading

The loading and unloading of vinyl chloride presents a special problem for the escape of vapors at detectable levels.

The proposed standard required that each transfer line and vapor-equalizing line be equipped with vent connections and have an inert gas purging system. Vent and purge effluent would be returned to a process stream or flared in a safe location. The proposal required that procedures for the transfer of vinyl chloride be developed and implemented.

(2) Emergency Situations

Operations involving the monomer have the potential for creating emergency situations in which significant leaks or spills occur. The proposal, therefore, required that a written operational plan for emergency situations be developed for each regulated area. Each employee was also to be trained to understand the hazards of vinyl chloride and the precautions for its safe use. In the event of an emergency, the decontamination of the affected area would be required before the resumption of normal operations. Special medical surveillance was also to be instituted within 24 hours for employees with known contact with VC. These employees were to be required to shower as soon as possible.

Medical Surveillance

Vinyl chloride in sufficient concentrations is known to cause changes in liver function. Liver dysfunction increases risk to health, possibly preceding the development of liver angiosarcomas. NIOSH has recommended the medical regulations

included in the proposal as reasonably appropriate to detect liver dysfunction. If specified biochemical determinations of liver function tests were abnormal, further screening was required. The employee would also be required to be withdrawn from areas where contact with vinyl chloride was possible.

Miscellaneous Requirements

(1) Waste Materials

The proposed standard required that waste materials be appropriately disposed of or decontaminated.

(2) Protective Clothing

The proposed standard required that each employee entering a regulated area be provided with full-body protective clothing, footwear or shoe covers, and gloves at no cost to them. The protective clothing required by the proposal would not only minimize skin contact with vinyl chloride vapor but would also protect the employee from splashes in the event of a spill or rupture of equipment containing liquid VC. Employees were to be required to remove all protective clothing upon leaving the regulated area.

(3) Hygiene Facilities and Practices

Shower facilities and change rooms were to be required under certain circumstances. Storage or consumption of food and beverages were to be prohibited in regulated areas.

(4) Signs and Labels

The proposal specified the signs and labels required at entrances, in regulated areas, on containers of waste materials contaminated with vinyl chloride, on containers of polyvinyl chloride containing detectable levels of vinyl chloride, and on containers of vinyl chloride.

(5) Reports and Records

The proposed standard required that monitoring and medical records be maintained for 20 years. In addition, reports identifying companies which have regulated areas, as well as other information, were to be provided to OSHA. Provisions regarding employee access to monitoring records were also included.

VI. PROBABLE IMPACT OF THE FINAL STANDARD*

Since January 1974, when the human carcinogenicity of vinyl chloride first became evident, significant measures were taken throughout the vinyl chloride and polyvinyl chloride industries to protect workers (as well as consumers of final products) by reducing the amounts of vinyl chloride to which they might be exposed.[1,7] The initial industry-wide efforts were relatively easy to institute as compared to the goals which are set by the proposed standard. The cost of continued reduction in exposure would be increasingly significant in industry and would ultimately be passed to the consumer.

1. Reduction in Worker Risk

Achieving a safe and healthful workplace in an effective and equitable manner has been OSHA's goal in the development of a standard for vinyl chloride. The available data suggest that to reduce worker risk, one must reduce to the maximum extent feasible worker exposure to vinyl chloride.

The animal studies and epidemiologic information (discussed more fully in chapter III) strongly suggest a cause/effect relationship between exposure to vinyl chloride and certain types of liver cancer, including angiosarcoma. The data also

*Note: References in this section have been selected as representative of testimony presented at the OSHA hearing of June 25, 1974. The cited references are in general not unique.

suggest that lower exposure levels are correlated to lower risk of occupational disease from vinyl chloride. However, the epidemiologic evidence is too inconclusive to estimate dose-response relationships with precision. Because the comparability between human and experimental animal physiology is not completely understood, the animal data provide only approximations of human susceptibility. Although the possibility of a threshold level of tumor induction may exist, the available scientific evidence does not establish a threshold level for vinyl chloride. In addition, the metabolism of vinyl chloride in the human body has not been conclusively delineated, and no proximate or ultimate carginogenic metabolities have been demonstrated.

Although knowledge of the quantitative relationship between vinyl chloride exposure and induction of human liver angiosarcoma is lacking, the experience of workers exposed to vinyl chloride and of animal studies provides cogent reasons for regulating workplace exposure. One of the primary impacts of the proposed standard will be to reduce, insofar as practicable, the risk of employees developing occupational disease from exposure to vinyl chloride.

2. Expected Impact on Industry

The vinyl chloride industry in the United States has become a vital component of the national economy since VC was first produced in 1930.[2] Applications of PVC tend to proliferate as rapidly as available supplies permit, even though there are few

market innovations. PVC has replaced many other materials because of its superior qualities. The history of PVC is replete with examples where, once it has penetrated a particular market, it has assumed a position of dominance.[3]

Prior to the current concern for reducing health hazards associated with exposure to VC, the industry was already somewhat unstable as VC production depends on the availability of petrochemical feedstocks which have been in short supply. The appearance of the OSHA standard may upset the existing uneasy balance; however, prediction of the exact nature of the impact on this complicated industry is fraught with uncertainties.

(1) Cost of Compliance

The most direct impact of the OSHA standard on industry will be the capital costs for implementing engineering controls and for purchasing monitoring, respiratory, and miscellaneous equipment. Monomer, compounding, and fabricating plants are likely to be less affected than polymer plants. According to industry estimates, the engineering changes required in polymer plants could well cost as much as the original capital expenditures for the plants.[4,5] Firestone estimates[5] a cost of $55 million to attempt to achieve a "no-detectable" level at two PVC plants. Altogether, approximately 37 plants would be required to make major investments.

The main sources of exposure in monomer plants are operations involving tank car loading, in-plant sampling, and laboratory

analysis. Additional emissions may come from process venting and from fugitive sources such as pumps, flanges, and valves. Costs for equipment to control exposures associated with tank-car loading and process venting will be substantial. Capital costs for the other items will be much less, since the emissions from these sources can be reduced primarily by work-practice methodology. Costs for replacing pumps, flanges, and valves to provide more leakproof equipment may be necessary. Engineering changes to reduce emissions from these sources will be also substantial, and the capability of achieving 1 ppm may not be technologically and economically feasible for all plants. Compared to engineering costs, expenditures for monitoring instrumentation, respiratory protective devices, and other equipment will be relatively low.[8] In general, the capital expenditures and time required to reduce VC concentrations to acceptable levels may be substantial.

Capital costs for compliance with the proposal in compounding and fabrication plants are not expected to be particularly high, but they still may be significant for some smaller companies.[4] In these plants, the greatest expenditures are expected to be for ventilation and monitoring equipment. Most companies already have installed ventilation equipment to control dust problems.[9,10] The cost of monitoring equipment may be several thousand dollars, but should be within the financial capability of large companies. For small companies, such purchases may be sufficiently prohibitive to upset their competitive position. However, such

companies may be able to satisfy their monitoring requirements by contracting for the services of industrial hygiene consultants rather than by purchasing equipment themselves, thus avoiding the capital cost of monitoring equipment.

The capital costs in polymer plants are likely to be substantial. Plants in this industry are so diverse that some may lose their competitive position, especially smaller firms with older equipment whose operations are already marginal. Previously, the heavy demands for PVC had ensured the continuance of such companies, but compliance with the proposed standard may prove to be an excessive strain. Several employers may find it necessary to close operations, concentrating the industry into fewer companies and causing disruptions of several markets.[2] It is also possible that demand for PVC would in the long term induce some companies to enter the market with larger and safer plants.

Substantial increases in energy requirements and in number of personnel may significantly increase direct operating costs. According to an industry spokesman, decreased efficiency of the equipment and lowered worker productivity may also have a significant impact on operating costs.[5] In all likelihood, a substantial price increase may be necessary to insure the viability of the industry. Since demand for PVC is stong and users have become dependent on this material, price increase will likely be accepted.

In situations in which several suppliers produce the same PVC product, the competitive position of individual companies may be seriously affected. However, the diversity of PVC types and characteristics may limit this type of impact to a small fraction of the companies involved. The standard may slightly improve the utilization of vinyl chloride feedstocks, since less would escape during processing and more would be reacted during polymerization.[7]

(2) Substitutes[12]

At present, there is no known material or materials which could substitute adequately for all the wide range of PVC uses. Historically, identification of a chemical as a carcinogen has resulted in an increased search for substitutes and a gradual decrease in its use. However, few previously identified chemical carcinogens have had a volume of production close to that of vinyl chloride. While there are substitutes for almost every use of polyvinyl chloride, such materials have been long abandoned for various reasons, such as scarcity, cost, and their inferiority to PVC. Furthermore, most PVC users indicated that they are now too dependent on this substance to permit a very rapid switch to other materials.

There is no evidence yet of a lessened demand for PVC (implying a concomitant shift to substitutes). The search for adequate substitutes may be heightened as the price of PVC resin increases, but any slackening of demand in one area would

likely be rapidly replaced by an increased demand elsewhere. There seems little likelihood of any total movement away from PVC unless it appears that U.S. industry cannot control the exposure hazards.

(3) Imports and Exports[5]

Vinyl chloride and polyvinyl chloride currently constitute relatively minor products in international trade. The demands for PVC resins are so great that each producing country is hard pressed to meet its own needs and is able to export very little. This situation will probably remain static for the foreseeable future, although an increase in prices caused by the OSHA regulation could alter this stability. If domestic prices increase substantially, PVC users may be able to obtain resins from manufacturers in countries where regulation is less strict. This is not likely to occur in the short run because of internal demands in all countries. In the long run, U.S. companies might find it profitable to build plants abroad. In any event, the extent to which the OSHA standard may impair the trade situation cannot be assessed at present, but some increased imports are expected.

(3) Miscellaneous Impacts

The OSHA standard may necessitate increased energy consumption in polymerization plants.[5] Increases in energy demand will

not be as great in monomer, compounding, and fabricating plants, although some rises may occur.

An adverse environmental effect of the standard may be a temporary increase in the amount of vinyl chloride entering the atmosphere as plants seek to eliminate VC from the workplace. Since vinyl chloride will readily disperse in the atmosphere, the increased background level of VC in the ambient air resulting from the standard will probably not be significant. The Environmental Protection Agency is examining the significance of levels presently found around various types of plants and will determine the necessity of imposing regulations to deal with VC emissions.

NOTES

1. Statement of Ralph L. Harding, Jr., Society of the Plastics Industry, at OSHA hearing of June 25, 1974 (Exhibit 20-B).

2. Statement of Vincent P. Ficcaglia, Arthur D. Little, Inc. at OSHA hearing of June 25, 1974 (Exhibit 20-F).

3. D. P. Keane, R. B. Stobaugh, and P. L. Townsend, "Vinyl Chloride: How, Where, Who-Future," Hydrocarbon Processing, February 1973, pp. 99-110.

4. Statement of Anton Vittone, B. F. Goodrich Chemical Company, at OSHA hearing of June 25, 1974 (Exhibit 20-D).

5. "Statement of Position of Firestone Plastics Company" presented as Exhibit 48-C at OSHA hearing of June 25, 1974.

6. Statement of John L. Nelson, B. F. Goodrich Chemical Company, at OSHA hearing of June 25, 1974 (Exhibit 27-A).

7. Statement of K. H. Oelfke, Dow Chemical Company, at OSHA hearing of June 25, 1974 (Exhibit 24).

8. Statement of Rodney P. Becker, Diamond Shamrock Chemical Company, at OSHA hearing of June 25, 1974 (Exhibit 20-R).

9. Statement of Louis J. Moliniusi, Gillot-Analytical Service Corp., at OSHA hearing of June 25, 1974 (Exhibit 20-Q).

10. Statement of Michael J. George, Canvas Products Association International, at OSHA hearing of June 25, 1974 (Exhibit 16).

11. Comment of Dow Chemical Company on Draft Environmental Impact Statement reproduced in Appendix C.

VII. ALTERNATIVES

The proposed OSHA standard is based on an evaluation of many factors, most of which are not readily quantifiable. In its development, many alternatives, both in general approach and in specific provisions, were evaluated. Although the limited amount of available time has precluded a definitive analysis of all the relevant factors, each section of the standard was based on a careful weighing of the available evidence. This chapter describes the major alternatives that were considered during the development of the proposed standard.

1. ALTERNATIVES CONCERNING THE SCOPE AND APPLICATION OF PROPOSED STANDARD

Polyvinyl chloride (containing entrapped vinyl chloride) eventually finds its way to companies which constitute over 10 percent of the national economy. Because of its widespread industrial use, the breadth of the standard's applicability has always been an important consideration. Polyvinyl chloride, even in products used by the general consuming public, apparently is always capable of releasing vinyl chloride. Thus, one alternative to the proposal would regulate all industries where VC or PVC might find application. This alternative is not supported by the data; the release of VC by most finished PVC products has not been documented. Once PVC has been heated to the point where it fuses, the amounts of vinyl chloride that can be released generally seem to be substantially reduced. It appears that finished or semi-finished PVC products are not capable

of releasing measurable amounts of vinyl chloride as long as they are not further subjected to temperatures such as those used in processing.

The position has also been proposed that compounding and fabricating plants handling PVC need not be covered by the OSHA regulation, but should be regulated by a separate standard. Indeed, it appears that no detectable or low levels of vinyl chloride will be observed in most compounding and fabricating plants.

Although there appears to be little or no VC in the breathing zones of most workers in the majority of these plants, measurable and perhaps significant amounts of vinyl chloride can build up inside heating and mixing vessels and in storage areas.

A significant amount of PVC used by fabricating companies is in pellet form. Since PVC pellets have already been subjected to processing temperatures, it is conceivable that most of the vinyl chloride that may have been entrapped in the PVC would have been released on this basis. The position has been advanced that

PVC pellets do not constitute a significant source of vinyl chloride and that fabricators using pellets do not need to be regulated. However, these pellets are subjected at other points in their processing to high temperatures, and it is not clear that further releases of VC do not occur.

Another alternative that has been raised is to distinguish between monomer and ploymer plants. Since these operations pose significantly different sets of hazards which may need to be regulated accordingly, it has been proposed that the OSHA standard reflect such differences.

It is possible that the monitoring provisions may affect many companies where VC hazards will not be found. It seems necessary to identify those companies where potentially hazardous exposures may occur. On the other hand, the exclusion of firms using finished or semi-finished fabricated products is not likely to exclude establishments with measurable levels of VC.

2. ALTERNATIVES CONCERNING LEVELS OF EXPOSURE

At any level of exposure except zero (which in effect would ban vinyl chloride manufacture), there may be a risk that a worker will contact liver angiosarcoma. However, a complete ban, causing a total shutdown of vinyl chloride or PVC plants, would severely disrupt the economy and worsen the employment situation. In all likelihood, a shutdown of VC and PVC plants would reverberate throughout the economy by effecting work stoppages in important sectors of the economy.

At the OSHA public hearing of June 25, 1974, many polymer producers stated that a requirement to reach a level of "no-detectable" VC upon the effective date of the standard would require them to shutdown. The producers claimed that the requisite technology to achieve a "no-detectable" level simply is not available; therefore, employees would be required to wear respirators at all times. The companies indicated that plants would close rather than attempt to meet this requirement. In any event, where engineering changes are needed, some time would be required.

Another alternative is to establish the permissible permanent level of exposure at or below 50 ppm. Risk estimates based on animal studies suggest the prudence of attaining TWA levels of exposure as low as feasible in all plants.

3. STAGING OF COMPLIANCE

Considerations of practicality must enter into the decision as to when companies will be required to comply with the particular provisions of the standard. As indicated at the hearing, many monomer and polymer producers already have initiated most of the actions needed to meet monitoring requirements. A problem arises with respect to the compounders and fabricators. If the alternative of immediate compliance with the monitoring procedures were adopted, industrial sources point out that the large number of companies involved would induce a severe shortage in supplies of monitoring equipment and of industrial hygiene consultants.

In evidence presented at the OSHA hearing of June 25, 1974, industrial sources claimed that a standard requiring immediate compliance to the proposed "no-detectable" level is not technically feasible in view of the massive engineering alterations that may be required.

If companies are required to meet the exposure level goal stipulated in the proposed standard, the companies have alleged that the practical effect would be to require employees to wear respiratory equipment at all times. A substantial amount of testimony was presented at the public hearing describing the difficulties of reliance on personal protective equipment. Some respiratory equipment is bulky and

cumbersome. Wearing certain types of this equipment continuously may strain workers, perhaps lessening their alertness. Some workers could suffer a claustrophobic effect and would be unable to use some equipment at all, even for short time periods. In addition, monomer plant layouts require workers to climb narrow ladders and traverse narrow catwalks in the normal performance of their duties, thus creating a potential safety hazard.

VIII. RELATIONSHIP TO OTHER FEDERAL ACTIONS

Production workers constitute the part of the population most obviously exposed to the hazards of vinyl chloride. However, in view of the fact that polyvinyl chloride products contain residual amounts of vinyl chloride which may be released, the general population may also be exposed, though as yet to an undetermined extent. Since vinyl chloride and polyvinyl chloride products find many uses throughout society, several Federal agencies in addition to OSHA have become concerned about possible population exposures to vinyl chloride. These agencies focused initially on the exposure that arose from the aerosol use of vinyl chloride; subsequently, efforts have been initiated to determine the extent to which vinyl chloride exposure occurs in other uses and the precise extent to which such exposures constitute a problem.

1. REGULATORY ACTIVITY

Historically, the only consumer use of vinyl chloride in monomer form has been as an aerosol propellant for hair sprays, pesticides, and other aerosol products. Tests conducted by the Environmental Protection Agency (EPA) and reported in the Federal Register on April 26, 1974, revealed that a VC aerosol released for 30 seconds sometimes produced concentrations as high as 400 ppm in the air of a closed room. By that time, manufacturers of aerosol hair sprays and pesticides indicated that they had voluntarily ended, in 1973, the use of vinyl chloride as a propellant. Nonetheless, some products containing vinyl chloride

probably still remained on the market even after this date. As a result, on April 26, 1974, EPA announced an emergency suspension of all pesticide spray products for indoor use containing vinyl chloride and also gave notice of its intent to cancel the registration of these products. At the same time, EPA requested that all existing stock of such products be recalled by the manufacturers.

On April 22, 1974, the Food and Drug Administration (FDA) published two proposed rules: one which would regulate the use of vinyl chloride as an ingredient of aerosol drug products such as in the form of a propellant; and another which would regulate the use of vinyl chloride as an ingredient (propellant included) of cosmetic aerosol products. Since evidence indicated that some supplies of hair sprays containing vinyl chloride were still on the market, FDA requested that all manufacturers initiate recalls for such hair sprays as well as for other drug and cosmetic aerosol products containing VC. On May 9, 1974, the Consumer Product Safety Commission commenced an information gathering process to determine the specific aerosol products which now use or have used vinyl chloride. It may ban the use of VC in aerosols for such products as spray paints, household cleaners, and de-greasing agents.

Significant programs are curre[illegible]derway to determine other areas where vinyl chloride or polyvinyl chloride formulations should be regulated. The Department of Transportation (DOT) currently regulates the shipping (46 CFR 145.24-100) and

transportation (49 CFR 172.5) of vinyl chloride as a flammable compressed gas. The containers that may be used are specified by these regulations. At present, DOT is considering whether any changes in its regulations are warranted by the fact that the chemical has been identified as a carcinogen. The major issue is whether a single exposure to the chemical can cause cancer. At present, DOT is considering changes in labeling requirements, but not necessarily in packaging regulations.

The Environmental Protection Agency is currently collecting and assessing data on: (1) the ambient emission and effluent levels of vinyl chloride in air and water from VC and PVC manufacturing plants; (2) the environmental impact of all disposal methods for vinyl chloride and polyvinyl chloride wastes; (3) the overall ecological effects of vinyl chloride. EPA has also collected data in a preliminary monitoring program covering seven industrial complexes containing 10 PVC and 2 VC plants. Similarly, it is receiving data concerning emissions and control from the VC/PVC industry under Section 114 of the Clean Air Act. The results of these studies will determine the need for EPA regulations.

At present, certain polyvinyl chloride formulations are sanctioned for use in food packaging, and hence are exempt from classification as food additives subject to pre-marketing clearance by the Food and Drug Administration. Early in 1973, FDA received reports that vinyl chloride was migrating to the interior surface of polyvinyl chloride bottles then being test marketed for alcoholic beverages. Use of polyvinyl chloride bottles for this

purpose ceased after the Commissioner of FDA issued a proposal which concluded that polyvinyl chloride bottles may cause the adulteration of alcoholic beverages.

There have been further reports of migration when polyvinyl chloride is used as an ingredient of containers for non-alcoholic products. Therefore, FDA has requested information on the extent of polyvinyl chloride usage by type of container and type of product, on the vinyl chloride content of polyvinyl chloride used to manufacture such containers, and on the level of and rate at which vinyl chloride can be extracted from such containers under certain test conditions.

FDA may establish maximum levels for the amount of the vinyl chloride that can be extracted from such polyvinyl chloride packaging. FDA has also requested that manufacturers submit information on every drug product containing vinyl chloride as an ingredient or packaged in polyvinyl chloride containers. FDA currently does not know whether vinyl chloride is being used in the manufacture of drug products.

2. RESEARCH STUDIES

Despite the fact that vinyl chloride and polyvinyl chloride have been present in large quantities in the U. S. for many years, little is known about their health effects. As a result, many studies have been initiated during the past several months, and others are being proposed.

The Center for Disease Control (CDC) is conducting a national search for all deaths from angiosarcoma of the liver which have been reported since 1965. For each case identified, the health history of the individual will be reviewed and analyzed to determine whether or not there had been any exposure to vinyl chloride or polyvinyl chloride. CDC is also conducting studies to determine deaths from other causes that may be related to exposure to vinyl chloride. In these studies, pathological information will be obtained from hospitals. A survey among meat wrappers in Houston, Texas presently underway will determine whether vinyl chloride released from polyvinyl chloride packaging materials may be the cause of "meat wrappers asthma."

The National Institute for Occupational Safety and Health (NIOSH), an agency of CDC, is conducting several studies on various aspects of the vinyl chloride question. The most significant effort is a comprehensive epidemiologic survey of workers from 11 polymerization and fabricating plants. Employee medical records are being subjected to intense screening to determine the scope and magnitude of vinyl chloride effects. All hospital data obtained in this study is being sent to CDC for its angiosarcoma search. NIOSH is also planning studies to determine if cosmeticians exposed to vinyl chloride from aerosol hair sprays have contracted any cases of liver angiosarcoma. NIOSH is examining the types of monitoring equipment that would be feasible for use in the workroom environment. The primary problem in this respect is developing monitoring equipment of greater sensitivity than was necessary in

the past when the principal concern was the explosive potential of vinyl chloride.

The Environmental Protection Agency will conduct epidemiologic studies of the neighborhoods surrounding selected VC and PVC production plants. In addition, studies are being made of the effects of vinyl chloride on developing rat fetuses, the effects of other stresses (such as ethanol and vinylidene chloride), and the importance of nutritional factors in vinyl choride toxicity.

The National Cancer Institute is conducting some cell culture studies to discover the carcinogenic mechanism of vinyl chloride. The Fish and Wildlife Service of the Department of Interior is concerned about the ecological effects of polyvinyl chloride piping, since the residues from such piping seem to give rise to liver problems in fish being raised in hatcheries. No clear statement as to the ultimate cause has been proposed, although a possible source of the problem may be the plasticizers used with the polymers.

The National Bureau of Standards (NBS) is performing some preliminary investigations into the development of permeation tubes which could serve as more accurate calibration sources for vinyl chloride monitoring equipment. NBS is also examining the mechanism by which residual vinyl chloride escapes from the polymer.

IX. COMMENTS

Those comments which have been submitted in direct response to the draft environmental impact statement on vinyl chloride are included as Appendix C to this report. In addition, the testimony of witnesses at the OSHA public hearing on June 25, 1974, was permitted to stand as comments on the draft statement. Accordingly, the discussion of the comments presented in this chapter will attempt to treat the complete record of the public hearing. Although some of the comments presented at the public hearing are reflected in those included in Appendix C, this appendix does not show the full range of the testimony presented at the public hearing. Since the testimony at the public hearing was not specifically directed at the impact statement, but more directly addressed the substance of the standard, no attempt is made to reproduce it here.

The testimony presented at the hearing and the comments on the draft environmental impact statement fall into three main categories: critiques of sections of the dfaft environmental impact statement; background information on the nature of the health effects of vinyl chloride, the sources of occupational exposure, and the methods of dealing with the hazard; and critiques of the provisions in the proposed standard (Appendix B). The first category is relatively small, since few participants at the hearing commented directly on the statement and few responses have been received during the period provided for public comment.

1. Comments on Draft Environmental Impact Statement

The comments shown in Appendix C primarily address the same issues as those discussed in the other two sections of this chapter. In addition, they also address specific statements made in the draft of this report. These latter comments fall into two categories: (1) those dealing with statements of fact; and (2) those dealing with the general tone and interpretation of data made in the draft impact statement. Suggested changes arising with respect to statements of fact have been accepted and are incorporated in the relevant portions of this final statement.

The second category of comments was concerned primarily with the discussion of the impact and the alternatives included in the draft. Since these same issues were dealt with by witnesses appearing at the public hearing, particularly in their predictions of the impact of the proposed standard, the relevant chapters (VI and VII) have been revised to reflect these comments.

2. NATURE OF BACKGROUND INFORMATION PROVIDED

A large number of witnesses at the public hearing presented evidence directly bearing on the health hazards associated with vinyl chloride. Generally, this testimony falls into the following areas:

- o Carcinogenicity of vinyl chloride in animals
  - Results of animal experiments
  - Interpretation of experiment results

Problems of extrapolation of results from animals to humans

- Mechanism of vinyl chloride carcinogenesis
- Unknown areas that await further study

o Carcinogenicity of vinyl chloride in humans

- Results of clinical studies
- Results of epidemiologic studies
- Problems in diagnosing angiosarcoma of the liver
- Interpretation of results of studies in terms of a "safe" level of exposure for humans

This testimony has been evaluated and incorporated into Chapter III of this report insofar as was possible in the time available.

The second major area of information provided at the hearing was the results of monitoring studies designed to identify the current levels of exposure in several types of plants and operations. Witnesses provided the following types of information: (1) the major sources of vinyl chloride in the workplace, identifying the types of equipment which constitute the major problems; (2) exposure levels observed in the plant and related to worker job categories; and (3) the relationship between residual monomer levels and the existence of an exposure hazard in compounding and fabricating plants. This information was provided for monomer, polymer, compounding, and fabricating operations. Much of this information has been provided in post-hearing comments which have been included in the hearing record. At this

time, the patterns that can be discerned from the data are relatively general in nature. To the extent possible, this information has been incorporated into Chapter IV.

The third major type of information provided at the hearing bears on methods for dealing with exposures in the various plants and operations. The primary areas of discussion dealt with: (1) methods of monitoring to detect the presence of vinyl chloride; (2) the ability of respiratory equipment to reduce exposure; and (3) engineering changes and work practice methods that could reduce exposures in each of the types of plants and operations.

3. COMMENTS ON PROVISIONS OF THE PROPOSED STANDARD

Testimony presented at the public hearing and comments received on the draft environmental impact statement dealt with the ability of the affected companies to comply with its provisions. The comments fall into two categories: (1) those discussing the feasibility and effect of the proposed standard taken as a whole; and (2) those dealing with specific provisions of the proposed standard.

In the first category of comments, witnesses described the structure of the PVC industry, demonstrating the interdependence of its various parts and the relationship to other parts of the economy. Witnesses demonstrated the effect of the proposed standard if certain of its requirements were imposed on industry. Industry witnesses were concerned with the technological feasibility of complying with the standard as proposed, specifically, the feasibility of installing engineering controls to achieve a "no detectable level". These issues are discussed in Chapter VI and VII.

The second category of comments on the proposed standard concerned specific language that was used. In most cases, the comments reflected the difficulties of interpreting certain provisions. In particular, these comments addressed the following parts of the proposed standard: (1) definitions of the terms "authorized employees," "contaminated," decontamination," "detectable level," emergency, "exposure," "fabricated product," and "waste resin;" (2) the accessibility of records to employees; (3) the nature of engineering controls for different types of

operations; (4) the necessity of certain requirements for hygiene facilities and practices and for protective equipment; (5) interpretation of the confidence level requirement for monitoring; (6) the necessity of specifying the medical surveillance requirements in detail; (7) the language to be used on signs and labels; (8) the correctness of the specifications for respiratory equipment; and (9) the length of time for record retention. A consideration of these comments have been incorporated into the discussion of the provisions of the proposed standard.

196(d)

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION
U. S. DEPARTMENT OF LABOR
Washington, D.C.

In the Matter of	)	
	)	
PROPOSED PERMANENT STANDARD	)	Docket OSH-36
FOR OCCUPATIONAL EXPOSURE	)	
TO VINYL CHLORIDE	)	

MOTION TO REOPEN HEARING, TO EXTEND THE TIME FOR THE FILING OF COMMENTS ON THE PRELIMINARY REPORT CONCERNING ECONOMIC IMPACT STUDY BEING CONDUCTED BY FOSTER D. SNELL, INC. AND TO ESTABLISH A DATE FOR SUBMISSION OF COMMENTS WITH RESPECT TO THE FINAL REPORT ON THE SAME SUBJECT

FIRESTONE PLASTICS COMPANY, a Division of THE FIRESTONE TIRE & RUBBER COMPANY, by its attorneys, respectfully moves that the public hearings in the above-captioned matter be reopened for the purpose of affording all interested parties an opportunity to meet and cross-examine all individuals who participated in the design, preparation and writing of the Preliminary Report and the anticipated Final Report of Foster D. Snell, Inc. on Economic Impact Studies of the Effects of Proposed OSHA Standards for Vinyl Chloride; to extend the time for the submission of comments with respect to said Preliminary Report and to establish a date for submission of comments with respect to said Final Report. In support of its motion, FIRESTONE states as follows:

1. Pursuant to objections to the proposed permanent standards for occupational exposure to vinyl chloride filed by

numerous interested parties, public hearings were scheduled and were held before the Honorable Gordon J. Myatt, Administrative Law Judge, on June 25 through 28 and on July 8 through 11, 1974, at the Departmental Auditorium, Department of Labor Building, 14th and Constitution Avenue, N.W., Washington, D.C.

2. At the conclusion of the public hearings, Judge Myatt ruled that the record would remain open until August 23, 1974 for the receipt of general comments, that the record would remain open for an additional period after August 23, 1974 solely for the submission of written comments on an economic impact study being conducted for OSHA by an independent consultant and that certification of the record pursuant to 29 C.F.R. §1911.17 would not occur until after the date set for submission of comments on the economic impact study (Tr. 1976-1979).

3. The Assistant Secretary of Labor of Occupational Safety and Health filed a notice which was published in the Federal Register on August 26, 1974, announcing the availability of the economic impact study conducted for OSHA by an independent consultant and specifying that written comments regarding the study would be received and considered provided that such comments were postmarked no later than September 6, 1974 (39 Fed.Reg. 30844 (1974)).

4. The economic impact study referred to above was conducted by Foster D. Snell, Inc. ("Snell") and was commenced

on July 11, 1974, two months after the issuance of the proposed permanent standard and 17 days after the start of the public hearings. A Preliminary Report was delivered to OSHA by Snell on August 23, 1974, and a Final Report is to be delivered to OSHA by Snell on September 13, 1974. Consequently, September 6, 1974, established as the postmark date for comments concerning the study, only provides interested parties an opportunity to comment on the Preliminary Report because the Final Report will not be submitted for the record until after the date for submitting comments has expired.

5. On August 23, 1974, Snell submitted its Preliminary Report entitled "Economic Impact Studies of the Effects of Proposed OSHA Standards for Vinyl Chloride" to OSHA. The decision of the Court of Appeals in Industrial Union Department, AFL-CIO v. Hodgson, 1 OSHC 1631, ___ F.2d ___ (D.C.Cir. 1974), determined that the economic impact of a proposed permanent standard for occupational exposure to a substance was a "crucial issue" for the Assistant Secretary in promulgating a standard under Section 6(b)(5) of the Occupational Safety and Health Act of 1970 ("Act"), 29 U.S.C. §655(b)(5) (1970). Only two reports on the economic impact of proposed standards for occupational exposure to vinyl chloride will be a part of the record in these proceedings (excepting the Arthur D. Little, Inc. report which relates to effects of the proposed standard on the entire U. S. economy): the study conducted by FIRESTONE and Snell's study as expressed in its Preliminary and Final Reports.

6. Crucial issues, which can only be resolved by cross-examination of the persons who designed, prepared and wrote the Snell Reports, are raised by a review of the Preliminary Report alone, for example:

(a) The need to obtain additional and specific information and data concerning the basis on which Snell determined capital cost estimates for various hypothetical exposure levels because Snell's Preliminary Report does not include any information or data indicating the bases on which it reached its conclusions or the actual information and data relied upon.

(b) The need for verification of sources and of data obtained from industry with respect to capital cost estimates for each hypothetical exposure level, particularly in view of the fact that Snell has totally misrepresented data presented by FIRESTONE with respect to ability to meet a non-detectable level of occupational exposure and excluded FIRESTONE's data from its capital cost estimates survey (as is more fully explained in the letter of August 27, 1974 from Todd C. Walker, attached hereto as Exhibit A). (See p. V-6 of Snell's Preliminary Report and Exhibits referred to in connection therewith.)

(c) The need for verification of sources and data obtained from industry with respect to estimated time to achieve the hypothetical exposure levels referred to in the Preliminary Report.

(d) The need for identification and verification of computational formulas for arriving at cost per pound estimates to be imposed on industry at each hypothetical exposure level.

(e) The need for explanation as to the basis for all conclusions reached by Snell as to "VCM levels potentially achieved" by industry and as to the absence of such conclusions in the Preliminary Report with respect to certain other hypothetical exposure levels.

(f) The need for explanation as to the absence of conclusions in the Preliminary Report as to estimates provided by Snell of the percent capacity of the industry subject to shutdown at all hypothetical exposure levels.

(g) The need for verification and specific identification of sources and information pertaining to estimates of time needed for deliveries of equipment deemed necessary for achieving compliance with hypothetical exposure levels.

(h) The basis on which certain process equipment and personnel protective equipment manufacturers and design engineers were selected to provide information and data, whereas accepted suppliers of such equipment and certain engineering firms having extensive experience in the PVC industry were not contacted to provide such information and data.

(i) The need for verification and specific identification of sources and information pertaining to Snell's conclusions as to estimated time for industry to comply with hypothetical exposure levels.

(j) An explanation as to the bases or reasons why the conclusions of the Preliminary Report with respect to cost per pound estimates in PVC plants generally exclude from consideration reduced numbers of PVC plants and total PVC capacities in increasing percentages as the various assumed hypothetical exposure levels are reduced.

(k) An explanation of the basis for selecting increasingly limited numbers of plants in differing age categories to prepare estimates of the cost per pound estimates for PVC plants generally.

(l) The absence of any data or supporting studies of engineering specialists by Snell directed to the issue of technological feasibility, as opposed to the impact on the economics of the industry.

(m) The absence of any data or supporting studies on the economic effect of hypothetical exposure levels on foreign competition.

(n) The absence of any data or supporting studies taking into consideration the economic impact and effects on competition resulting from the geographic distribution

of PVC plants as shown in Exhibit III-6 of the Preliminary Report.

(o) The need for explanation and detailed information and data of the factors taken into consideration in determining the capital costs of the so-called "grass roots" plant described in Exhibit IV-13 and whether such costs include acquisition and purchase costs of the land and the costs for common services, such as utilities, water treatment, etc.

(p) The need for explanation, specific information and data and identification of sources utilized as a basis for the cost estimates of monitoring equipment at pages V-14-15 when compared with the FIRESTONE data included in its written presentation.

(q) The need for explanation as to the reason the Preliminary Report neglected to include at page V-18 the medical costs of bi-annual examinations for employees with more than ten years of employment as required in the proposed permanent standard.

7. Moreover, equally important, if not more significant, crucial issues are raised by the proposed inclusion in the Final Report of detailed studies and material, which interested parties will not even have a chance to comment upon, and which can only be resolved by cross-examination, for example:

(a) An analysis of cases representing potential exposure limits between "no detectable and 25 ppm" (p. II-5, Preliminary Report).

(b) "Data refinement" where indicated in the body of the Preliminary Report (p. II-5, Preliminary Report).

(c) The 35,000 gallon reactor technology (p. II-5, Preliminary Report).

(d) Polymerization cycles and reactor cleaning (p. II-5, Preliminary Report.

(e) Monomer stripping (p. II-5, Preliminary Report).

(f) Carbon absorption (p. II-5, Preliminary Report).

(g) General R&D (p. II-5, Preliminary Report).

(h) The case study of a PVC plan "representative of the industry with good exposure data and assumed to be under a 10 or 15 ppm TWA" (p. VI-1, Preliminary Report).

(i) The need for detailed explanation and identification of sources of data and information relied upon in stating a potential time table for implementation of a hypothetical continuous polymerization plant, as stated in Exhibit C-2(5)(6), and the extent to which engineering and technologies presently are capable of implementing such a plant or those which may be developed in the immediate future.

8. Section 1911.15(a)(2) and (a)(3) of OSHA's Rules and Regulations (29 C.F.R. §1911.15(a)(2) and (a)(3)) recognized the fundamental importance of the right to cross-examination in the development of a record subject to the substantial evidence test under Section 6(f) of the Act (29 U.S.C. §655(f) (1970)), as follows:

> "(a) * * * (2) Section 6(b)(3) provides an opportunity for a hearing on objections to proposed rule making, and section 6(f) provides in connection with the judicial review of standards, that determinations of the Secretary shall be conclusive if supported by substantial evidence in the record as a whole. Although these sections are not read as requiring a rule making proceeding within the meaning of the last sentence of 5 U.S.C. 553(c) requiring the application of the formal requirements of 5 U.S.C. 556 and 557, they do suggest a Congressional expectation that the rule making would be on the basis of a record to which a substantial evidence test, where pertinent, may be applied in the event an informal hearing is held.
>
> "(3) The oral hearing shall be legislative in type. However, fairness may require an opportunity for cross-examination on crucial issues. The presiding officer is empowered to permit cross-examination under such circumstances. The essential intent is to provide an opportunity for effective oral presentation by interested persons which can be carried out with expedition and in the absence of rigid procedures which might unduly impede or protract the rule making process.
>
> "(b) Although any hearing shall be informal and legislative in type, this part is intended to provide more than the bare essentials of informal rule making under 5 U.S.C. 553. The additional requirements are the following:

"(1) The presiding officer shall be a hearing examiner appointed under 5 U.S.C. 3105.

"(2) The presiding officer shall provide an opportunity for cross-examination on crucial issues.

"(3) The hearing shall be reported verbatim, and a transcript shall be available to any interested person on such terms as the presiding officer may provide." (Emphasis added)

9. Cross-examination with respect to the facts concerning crucial issues is the handmaiden of trustworthiness, a right and fundamental element of procedural due process. Interstate Commerce Commission v. Louisville & Nashville R. Co., 227 U.S. 88 (1912); Alford v. United States, 282 U.S. 687 (1931); Morgan v. United States, 304 U.S. 1 (1937); National Trailer Convoy, Inc. v. United States, 293 F.Supp. 634 at 636 (1968); Appalachian Power Co. v. Environmental Protection Agency, 477 F.2d 495 at 503 (4 Cir. 1973). OSHA's representatives at the hearing conducted extensive cross-examination of all interested persons with respect to the facts concerning crucial issues, including the economic impact of the proposed standards for occupational exposure to vinyl chloride. Yet, the developers, preparers and authors of the Preliminary Report, which was commissioned by OSHA and one of the two reports in the record on the issue of economic impact, have not been subjected to cross-examination on their procurement, development and analysis of critical facts. Moreover, the Final Report which will contain critical matters not touched upon in the Preliminary Report is

to be included in the record without even an opportunity for comment. Such a procedure not only violates the fundamental concepts of elemental due process but also squarely contravenes fundamental fairness.

10. The Rules of Procedure for promulgating, modifying or revoking occupational safety or health standards adopted by the Secretary of Labor pursuant to Sections 6(b) and 8(g) of the Act specifically require, as noted above, that the presiding officer provide an opportunity for cross-examination on crucial issues (§1911.15(a)(3), 29 C.F.R. §1911.15(a)(3)). Section 1911.16 of the procedural rules and regulations specifically requires the officer presiding at a hearing to conduct a fair and full hearing and enumerates, inter alia, the powers of the hearing officer as follows:

> "The officer presiding at a hearing shall have all the powers necessary or appropriate to conduct a fair and full hearing, including the powers:
>
> "(a) To regulate the course of the proceedings;
>
> "(b) To dispose of procedural requests, objections, and comparable matters;
>
> * * *
>
> "(e) In his discretion, to permit cross-examination of any witness; * * *." (Emphasis added)

11. Administrative agencies are required scrupulously to follow their own procedures even where the procedures adopted

by the agencies are more rigorous than otherwise would be required. Morton v. Ruiz, ___ U.S. ___, 39 L.Ed.2d 270 at 294 (1974). Thus, as stated in Pacific Molasses Co. v. F.T.C., 356 F.2d 386 at 389 (5 Cir. 1966):

> "When an administrative agency promulgates rules to govern its proceedings, these rules must be scrupulously observed. See Service v. Dulles (1957), 354 U.S. 363, 77 S.Ct. 1152, 1 L.Ed.2d 1403. This is so even when the defined procedures are '* * * generous beyond the requirements that bind such agency * * *.' Vitarelli v. Seaton, (1959), 359 U.S. 535, 547, 79 S.Ct. 968, 3 L.Ed.2d 1012 (Justice Frankfurter dissenting). For once an agency exercises its discretion and creates the procedural rules under which it desires to have its actions judged, it denies itself the right to violate these rules. United States ex rel. Accardi v. Shaughnessy (1954), 347 U.S. 260, 74 S.Ct. 499, 98 L.Ed.681. * * *"

See also, Yellin v. United States, 374 U.S. 109 (1963); United States v. Leahey, 434 F.2d 7 (1 Cir. 1970); Hollingsworth v. Balcom, 441 F.2d 419 (6 Cir. 1971). Failure to provide interested parties an opportunity to cross-examine the authors of the Snell Reports containing data and information directly related to crucial issues clearly violates the rules of procedure and regulations adopted by the Secretary of Labor and deprives interested parties of an opportunity for a "fair and full hearing" as is expressly required by the procedural rules and regulations adopted by the Secretary.

WHEREFORE, FIRESTONE PLASTICS COMPANY respectfully requests that the hearing herein be reopened for the sole purpose of affording interested persons an opportunity to cross-examine those individuals who prepared, developed or authored the Preliminary and Final Reports of Foster D. Snell, Inc. on Economic Impact Studies of the Effects of Proposed OSHA Standards for Vinyl Chloride, and that the Administrative Law Judge be authorized to establish a new date for receipt of comments on the Preliminary Report and a date for receipt of comments on the Final Report at the conclusion of the reopened hearing.

Respectfully submitted,

FIRESTONE PLASTICS COMPANY

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Dated: August 29, 1974

CERTIFICATE OF SERVICE

The undersigned hereby certifies that a copy of the foregoing Motion was mailed on August 29, 1974 to the following:

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Administrative Law Judge
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John J. Cassidy, Jr.

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BEFORE THE
OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION
UNITED STATES DEPARTMENT OF LABOR

Health Research Group	) Comments	Docket No. OSH-36

IN THE MATTER OF THE ECONOMIC IMPACT STUDY
ON THE PROPOSED PERMANENT STANDARD ON OCCUPATIONAL
EXPOSURE TO VINYL CHLORIDE

The Health Research Group, Public Citizen Inc., a public interest organization involved in research and advocacy on occupational health, offers the following comments on Economic Impact Studies of the Effects of Proposed OSHA Standards for Vinyl Chloride: Preliminary Report, Contract No. L/A 74-167, prepared by Foster D. Snell, Inc. for consideration in the proceedings on the proposed permanent standard for vinyl chloride. The proposed standard was published at 39 Fed. Reg. 16896 (May 10, 1974) and these comments are submitted pursuant to the notice of availability of the economic impact study published at 39 Fed. Reg. 30844 (August 26, 1974).

ECONOMIC FEASIBILITY: THE STATUTORY CRITERIA

The broad issue of "economic feasibility" involves two distinct regulatory considerations. First is the permissible function of economic data in the promulgation of occupational safety and health standards under section 6(b)(5) of the Act,[1] and second is the burden and quantum of proof necessary to establish economic infeasibility when this defense is raised by industry. With respect to the first consideration, we renew our fundamental objection to the consideration of economic feasibility per se in OSHA standard-setting.[2] However, the following comments will be based on the argumentative assumption that the narrow economic considerations authorized in the judicial review of the asbestos standard will withstand subsequent review.[3]

Section 6(b)(5) provides that the Secretary shall "...set the standard which most adequately assures, to the extent feasible...that no employee will suffer material impairment of health or functional capacity...." 29 U.S.C. s 655(b)(5). The textual authority for economic considerations relied on by the Court in the asbestos case is the term "feasibility".[4] While the Court concluded that the term "feasibility" might extend to economics, it is essential to note that the Court did not mandate the consideration of economics. Rather the Court concluded that economics was merely a permissive criterion in assessing the

practicability of the standard.[5] Moreover the Court did not interpret the statute to authorize the wholesale dilution of occupational safety and health standards based on the economic fears of industry; it stated that economic feasibility "...is not intended to provide a route by which recalcitrant employers or industries may avoid the reforms contemplated by the Act...."[6] Finally, infeasibility does not exist simply because the standard is financially burdensome or adversely affects profit margins. As the Court tersely pointed out, "Nor does the concept of economic feasibility necessarily guarantee the continued existence of individual employers...."[7]

The restricted function of economic data in standard-setting is a recognition that compliance inevitably results in economic impact. In fact, the purpose of mandatory standards is to compel each affected employer to make the necessary investments in the workplace and its operations so that the indifferent employer is not competitively advantaged by his disregard for worker safety and health.[8] Furthermore the statute provides specific economic relief for small businesses,[9] as well as other variance remedies.[10] The statutory assistance offered to small businesses indicates Congressional intention that compliance costs are to be absorbed as the cost of doing business ("internalization") and that alternative compliance techniques and demonstrated hardship would be considered in individual cases. Therefore, economic

feasibility must involve extraordinary costs which are not diminished by the personal, social and industrial costs of continued disease and injury, and which are not counterbalanced by the savings of the improved health and functional capacity of workers.

Judicial interpretation and statutory analysis not only severely restrict the consideration of economic data in the standard-setting process, they direct that economic infeasibility shall be demonstrated by detailed and specific proof. An employer may not mask his recalcitrance behind simplistic expressions of concern for worker health or generalizations about economic infeasibility. As the general counsel for the Society of Plastic Industry recognized, industry has the responsibility to obtain "hard data" in fulfilling its obligation to make the record as "comprehensive, objective and complete as possible".[11] Vague generalities, self-serving assumptions, and unsubstantiated analyses must be excluded from consideration. Moreover, this case must not be confused with cases where evidence is not presently available from any source.[12] Rather this is a case where the evidence on economics is immediately available to industry by exclusive possession of corporate books, reports and records. Nonetheless, industry persists in its assertion that the Secretary must draw the inference of economic infeasibility despite its own refusal to submit all economic data regarding its fi-

nancial condition and the state of the technological art. Moreover, the suggestion that data involving economic and technological feasibility is privileged because it involves trade secrets is virtually untenable. Section 15 of the Act[13] relating to trade secrets is not a basis for denying the Secretary access to the information; it simply provides a penalty against government employees who subsequently disclose trade secrets submitted to the Secretary. Since the data is within the exclusive control of the employer, it is entirely appropriate to place the burden of proof (production and persuasion) regarding economic feasibility on those who make this claim. Similarly the traditional evidentiary rule must be applied which draws an adverse inference from the employer and the industry's failure to produce all relevant data.[14]

METHODOLOGY OF THE ECONOMIC IMPACT STUDY

The contracted study prepared for the Occupational Safety and Health Administration purports to be an economic impact study of the various alternative standards for vinyl chloride. However, the preliminary report reveals that the expected study of economic impact has in fact attempted to concentrate on technological feasibility.[15] The unfortunate result of this double assignment is that the study fails to satisfy either objective as a result of input deficiencies and analytical inadequacies.

Moreover, the study devotes most of its time to the alternatives to the proposed permanent standard of "no detectable" exposure, i.e. 50 and 25 ppm ceilings, 25 ppm TWA with 40 ppm ceiling and lower TWAs.[16] To a large measure this improper bias is based on the contractor's acceptance of the industry position that the standard of "no detectable" exposure is "infeasible".[17] But these fundamental errors pale in contrast to the purposeful definition of economic impact (either by the contractor or the Assistant Secretary) as the "direct cost impact on the VCM and PVC industries."[18] This myopic concentration on compliance costs disregards entirely the personal, social and even industrial costs of continued disease as well as the savings from improved health from the elimination of worker exposure to vinyl chloride. These critical omissions make the study legally insufficient with respect to any conclusions involving economic infeasibility or the assessment of total cost impact.

Input Deficiencies

The reliability and validity of the conclusions drawn from the data analyzed by the contractor is initially dependent on the accuracy and thoroughness of the information-gathering process. Chapter II of the study indicates that field (plant) visits, technical discussions, and telephone interviews comprised the major surveying techniques.[19] However, the preliminary report fails to include a copy of the detailed interview and sur-

vey protocols. It is, therefore, impossible to examine the reliability of the survey, the validity of the responses or the soundness of any conclusions drawn from the data base. The importance of this survey protocol is re-emphasized by the failures to provide sources for numerous conclusions and tabulations. For example, in attempting to describe the polymerization process at American Chemical, the Ethyl plants, Dow-Plaquemine and the Monochem plant, the contractor was compelled to preface his statement with the phrase "...is believed to feature...."[20] The failure of the data collection system employed by the contractor is obvious especially when two of these companies had actually been visited by a study team. Moreover, in surveying the state of the technological art with respect to VCM, no study team or investegator met with Dow Chemical engineers and technical experts,[21] one of the few companies with three generations of synthesis plants. The importance of these omissions is the fact that the study purports to be an analysis of technological feasibility yet its technical discussions did not involve either Dow Chemical or Firestone--two corporations prominently involved in this standard-setting procedure. No explanation of the selection of the companies involved in technical discussions is supplied in the report.

Moreover, the study fails to identify the composition of the study teams who conducted the surveys and interviews and the

qualifications of the company participants. The use of technology discussions suggests the deficiency of a plant visit as a basis for sound technological judgment. Finally, the contractor claims to have discussed "technological feasibility" with the trade associations,[22] yet the preliminary report never references these discussions in its assessment of available technology. Thus, either these associations provided information whose use the contractor refuses to disclose or these discussions were insignificant.

The study, however, suffers from other serious input deficiencies involving the thoroughness of the investigation. While this study presumes to be a study of technological feasibility, the contractor accepts certain fundamental representations of industry that the "no detectable level" standard is infeasible.[23] Unfortunately, the study lacks any definition of the admittedly complex term "techological feasibility" by either the contractor or the individual companies. Furthermore, Appendix C indicates that the contractor was not supplied with proprietary information.[24] Company refusals or contractor ineffectiveness could account for this and the preliminary report provides no criteria to evaluate claims of confidentiality.[25] The failure to obtain these data makes the report basically a compilation of industry characterizations selectively supported by the information it elected to disclose.

Analytical Inadequacies

Intimately related with the input deficiencies of the study is the adequacy of the analytical framework to measure the basic problem in issue. While the contracted report appears to be an economic impact study, it fails to assess the entire range of economic impact by concentrating exclusively on compliance costs. Conversely, as a technological feasibility study, it fails to actively investigate the state of the technological art or industry's representations about it. The study does not even include a definition of "technological feasibility" against which the contractor will measure the relative capabilities of the industry.

Technological feasibility has been a critical issue in the enforcement of other standards, most notably noise[26] and the threshold limit values of air contaminants.[27] Furthermore, the U.S. Court of Appeals for the District of Columbia Circuit considered the problem of feasibility generally. Its reference to laggard employers is critical to any evaluation of technological or economic feasibility. The Court observed "...it would appear to be consistent with the purposes of the Act to envisage the economic demise of an employer who has lagged behind the rest of industry in protecting the health and safety of employees and is consequently financially unable to comply with new standards as quickly as other employers...."[28] In discussing technological

feasibility specifically, it describes "protective devices unavailable under existing technology"[29] and "protective measures technologically achievable".[30] Thus, the Court is discussing achievable technology as well as existing technology. Moreover, in assessing the state of the technological art it is critical to remember Congressional aversion to consensus standards which are no more than the lowest common denominator.[31] The Court's discussion reflects a similar emphasis in its requirement of existing or achievable technology. The preliminary report not only fails to define technological feasibility, it evidences no sensitivity to the distinctions to be drawn with respect to technological capabilities--distinctions which are central to any findings or recommendations it makes in its final report. For example, Appendix C contains a reference to a production method which elicited a statement from an unidentified respondent who claimed the method was "highly uneconomical".[32] However, it is entirely inappropriate to reference such a statement without any consideration of the respondent's status as a "laggard" or the competitive disadvantage to the respondent of the particular method. Without such qualifying information, the statement is valueless in assessing the technological or economic feasibility of the process.

There is, however, another type of laggard whose difficulties economically and technologically deserve no recogition what-

soever in these proceedings. That is the employer who has failed to attain even the minimal requirements of the emergency temporary standard.[33] That employer fails to enter this forum with clean hands and any expenditures which would be necessary to meet the 50 ppm standard must automatically be discounted from any estimates of compliance costs. Not only might such an employer start from a position with greater options than those who have complied, it is also unfair to those who achieved compliance. Furthermore, the expenditures necessary to reach the emergency standard level must be discounted wherever the employer has failed to attain that level regardless of the employer's success in other operations. On October 5th, when the permanent standard must replace the emergency standard, compliance with the 50 ppm level must be accomplished; the failure to do so, and the additional cost it may require, merits no attention in an economic feasibility study.

The preliminary report also employed another criterion in making its assessment that price increases were "reasonable".[34] No lawyer would fail to recognize the inherent problems with any "reasonableness" test and therefore the necessity for the description of the model. For example, if "reasonable price" means a "market price" then the definition is valueless since "market price" is dependent on supply-demand relations which are the object of the economic impact study being conducted. If, however,

"reasonable price" is to be determined in line with commercial law traditions then appropriate considerations must be identified, e.g. resale on breach of a sales contract.[35] The study provides no such model. Finally, if the definition of reasonable price has been derived from the survey conducted by the contractors, it is essential to describe parameters identified by the respondents. "Reasonable" as a measure of acceptability to the industry serves a useful function in articulating the presently tolerable price increase. However, as a measure of an "unreasonable price" or as a negative inference, the concept of "reasonable price" is valueless unless the factors for determining a price to be unreasonable are surveyed and identified. For example, an employer engaged in polymerization might consider the price of VCM "unreasonable" simply because it adversely affected what the employer considered to be an acceptable profit-margin. This individual standard of "unreasonableness" determined on ad hoc basis provides no data base for any conclusion about a "reasonable price".

One remaining analytical criterion deserves specific mention. The use of the order of magnitude test[36] as a basis for concluding that company estimates are erroneous not only obscures the magnitude of the actual error, it is far too selective in assigning error. Thus, as the cost estimate increases the actual amount of the error is increasingly obscured. For example, cost esti-

mate of $40 which actually costs $4 is in error by $36. However, a cost estimate of $4 million which actually costs $400,000--again a difference of <u>one</u> order of magnitude--is in error by $3.6 million! Any cost which survives the order of magnitude test at the cost estimates offered by industry is certainly in error. The insensitivity of this test in this critical area is unacceptable in the standard-setting process.

THE SHUTDOWN SCARE

The economic impact study prepared for the Labor Department commits the same fundamental error as an earlier study for the vinyl chloride industry prepared by the Arthur D. Little Company. It accepts unquestioningly the industry assumption that it is technologically unfeasible to comply with a standard of "no detectable level" for VCM firms.[37] This irresponsible action is tantamount to assuming the virtual cessation of the industry as the industry contractor did. Attempting to obscure this assumption in the numerous standards alternatives generated by the Labor Department is an obvious evasion of the government contractor's responsibility to investigate the factual validity of industry's claims in light of the serious toxicological significance of <u>any</u> human exposure to a carcinogen. Moreover, this unthinking assumption incorporates wholecloth the incessant chorus of industry witnesses parroting the claim of industry unsubstantiated by any probative evidence.

The directive on shutdowns issued by the Court of Appeals in the asbestos case is explicit. The Court stated:

> ...Nor does the concept of economic feasibility necessarily guarantee the continued existence of individual employers....[38]

Additionally, the Court recognized that this shutdown might legitimately result from a competitive disadvantage caused by a firm's inability to abate expeditiously the hazard.

> ...It would appear to be consistent with the purposes of the Act to envisage the economic demise

> of an employer who has lagged behind the rest of the industry in protecting the health and safety of employees and is consequently unable to comply with standards as quickly as other employers....[39]

Thus the question of economic feasibility turns on the financial viability of industry generally,[40] a situation which occurs only when numerous firms are seriously threatened by shutdowns. This point is emphasized by the Court's distinction between the immediate inability to comply without delayed effective dates and the termination of operations.[41] Therefore, the threat of a shutdown as a question of economic feasibility materializes only when the composite of each firm's economic impact results in the complete destruction of the financial viability of the total industry. Threats and generalizations about individual shutdowns are totally irrelevant; the only possible consideration is that the industry as a whole will be threatened as a result of numerous individual shutdowns.

Initially, it must be noted that immediate cessation of all production by the entire industry is highly unlikely. Notwithstanding trade association generalizations, the determination to shut-down will be exercised by each firm based on its own assessment of its individual market strength. Moreover, the economic strength of the industry generally betrays the trade association threats.[42]

In a competitive industry, the shutdown of the industry would occur under the following economic principles.[43] Once compliance with the standard is required, the individual firm will be confronted with two operating alternatives: install the neces-

sary equipment to abate the hazard and pass on the costs in higher industry-wide prices or shutdown. The alternative selected by the firm will depend basically on its individual operating efficiency. The firm will take the former course if its total revenue exceeds its variable costs,[44] then the firm will continue to produce until the increase in variable costs plus its present variable costs exceed its total revenue. The firm should then consider shutdown since its total revenue does not meet its out-of-pocket or variable costs. This is as it should be because in this case the benefits to society from producing vinyl chloride are less than the costs counting human and health costs. However, if the firm is producing significantly above the shutdown point, i.e. total revenue equals or exceeds its total costs, fixed plus variable, then the increase in variable costs must be extraordinary to place this firm in a situation comparable to the marginal firm. (See Figure 1).

Of course, the marginal firm cannot continue production near its shutdown point over the long run because the fixed cost expenditures will become a permanent drain on its resources. Nonetheless, the prospect of long-term gain will serve as inducement to remain in operation. This is true of the marginal firms of the vinyl chloride industry who are the beneficiaries of a steadily increasing demand for their product and a high level of profit. Therefore, the importance of shutdown analysis probably disappears entirely with respect to a strong industry such as vinyl chloride. This occurs because there are few, if any, marginal firms and because even those firms which are economically dis-

advantaged will be willing to suffer short-term losses in light of the potential for long-term gain.

The strength of the industry is indicated by a number of critical determinants. PVC output has risen about 70% during the last 5 years for a compound growth rate of 11% per year.[45] The Snell study reports that demand remains strong,[46] and the entire industry is confident of long-run return: investment in 1974 will be 37.4% higher than in 1973, which follows an equally robust 25% increase from 1972.[47] These figures take on added significance in light of the general downturn in the economy during this period. Additionally most of the firms are producing at a point well above a thin break-even point (long run equilibrium point)--a point where the total revenue slightly exceeds the total cost or where the marginal cost of producing the last unit of production equals the average cost per unit. Exactly how far each firm is above the break-even point is impossible to determine since industry has consistently failed to provide precise data on profit margins. Nonetheless, individual firms have indicated full confidence in their industry through steadily increasing reinvestment from 23% increase in 1972 over 1971, to a 37% increase in 1973 over 1972.[48] While Business Week reports significant profit increases the monomer and polymer industry (Table 1), the economic impact study hypothetical construct includes a only 20% pre-tax profit.[49]

The thrust of industry's arguments in these proceedings has been to de-emphasize its financial strength and to characterize its flexibility, i.e. the difference between its total revenue

TABLE 1: Economic Strength of the Industry

Company	Rank: Fortune 500	Sales[a] ($ thousands) 1970	Sales[a] ($ thousands) 1973	Sales[b] ($ thousands) 2d Qtr. 1974	Sales[b] ($ thousands) 6 Months 1974	2d Qtr./ 6Mos.[b] Percent Change from 1973
Air Products	360	261,366	398,901	156,100	292,400	+51/+57
Allied Chemical	95	1,248,479	1,664,551	567,700	1,043,200	+31/+27
American Chemical*	-	-	4,603,914	2,004,500	3,729,000	(+64)/(+67)*
Conoco	21	-	4,224,004	1,831,600	3,445,100	+78/+76
Diamond-Shamrock	242	555,839	651,092	240,000	445,000	+46/+43
Dow Chemical	38	1,911,105	3,067,888	1,325,400	2,342,000	+77/+61
Ethyl Corp.	227	556,856	699,002	263,500	459,800	+47/+34
Firestone	37	-	3,124,919	851,000	1,636,400	+8/+12
General Tire	121	-	1,379,966	420,000	756,400	+22/+17
B. F. Goodrich	89	-	1,721,928	528,900	971,700	+24/+19
Goodyear	19	-	4,675,265	1,368,000	2,543,300	+13/+12
Hooker Chemical**	36	-	3,178,276	1,605,200	2,940,100	+98/+97
[redacted]						

Net Plant[c] & Equipment ($ thousands)	Net Income[a] ($ thousands) 1970	1973	Profits[b] ($ thousands) 2d Qtr. 1974	6 Months 1974	2d Qtr./6 Mos.[b] Percent Change From 1973
356,786	15,012	24,059	11,400	20,600	+70/+66
946,077	43,062	95,071	50,500	83,900	+72/+67
-	-	316,585	160,200	279,500	(+104)/(+197)
-	-	242,664	100,400	209,600	+94/+111
457,836	30,092	50,471	25,600	46,400	+71/+88
1,778,424	129,975	271,148	178,100	261,700	+124/+90
281,380	35,582	52,884	19,600	33,300	+37/+26
-	-	164,861	44,400	76,100	+3/+9
-	-	76,846	23,400	36,900	-3/-4
-	-	56,057	26,500	41,500	+53/+36
-	-	184,756	61,500	106,800	+10/+6
-	-	76,763	92,600	160,400	+293/+403
1,152,400	77,873	[illegible]	[illegible]	[illegible]	[illegible]

Company	Rank: Fortune 500	Sales[a] ($ thousands) 1970	Sales[a] ($ thousands) 1973	Sales[b] ($ thousands) 2d Qtr. 1974	Sales[b] ($ thousands) 6 Months 1974	2d Qtr./6 Mos Percent Change from 1973
National Starch	-	-	-	69,300	131,500	+27/+24
Olin Corp.- Thompson Plastics	137	1,125,301	1,239,292	361,600	686,500.	+42/+38
Shell Oil	18	-	4,883,808	2,177,900	4,071,400	+52/+50
Stauffer Chemical	253	482,543	621,329	204,500	429,000	+31/+31
Tenneco	29	-	3,910,472	1,238,900	2,353,900	+27/+26
Union Carbide	28	3,026,326	3,938,800	1,328,500	2,438,200	+38/+31
Uniroyal	72	-	2,082,691	629,100	1,159,300	+10/+10
Chemical Industry				12,494,600	23,155,000	+34/+29

* Jointly owned by ARCO, a division of Atlantic-Richfield, and the Stauffer Chemical Co. Figures are the cumulative sales, net income and profits of the joint owners. Parenthetical percentages are for Atlantic-Richfield only.

** Subsidiary of Occidental Petroleum Corp. Figures are those of the parent corporation.

[a] Chem. & Eng. News, June 3, 1974, at 34-41; Fortune, May 1974, at 232-251.

[b] Business Week, Aug. 10, 1974, at 92.

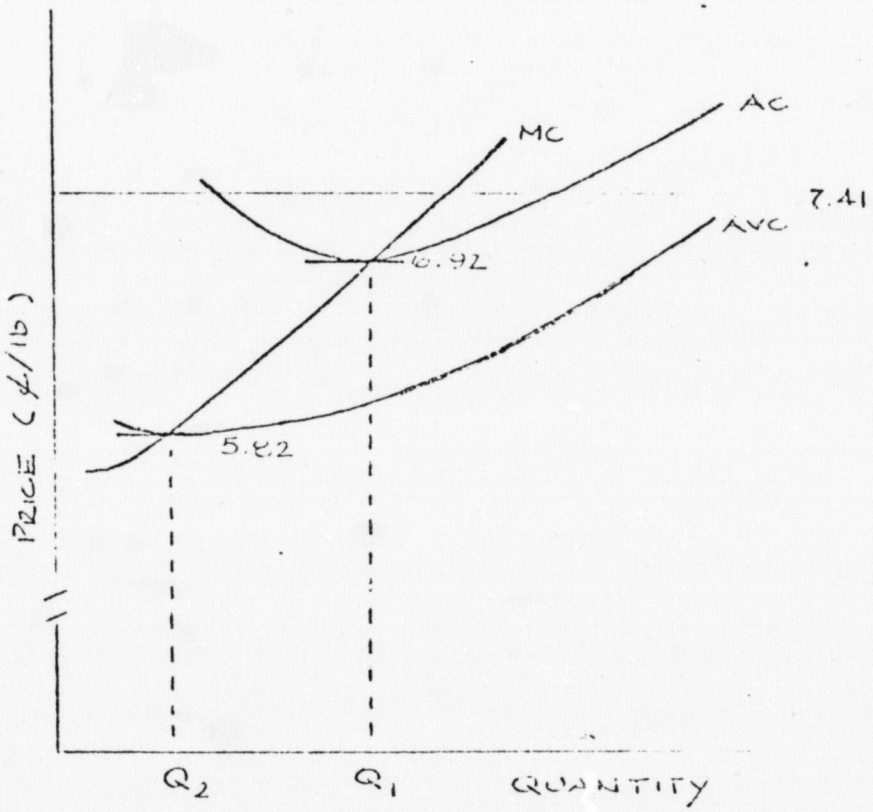
[c] Chem. & Eng. News, supra.

Net Plant[c] & Equipment ($ thousands)	Net Income[a] ($ thousands) 1973		Profits[b] ($ thousands) 2d Qtr. 1974	6 Months 1974	2d Qtr./6 Mos.[b] Percent Change From 1973
-	-	-	5,400	10,200	+20/+16
563,354	26,589	47,681	17,300	29,400	+78/+75
	-	332,694	124,500	246,300	+39/+45
297,618	25,979	46,400	20,500	45,900	+79/+65
-	-	230,211	87,600	171,600	+106/+79
1,991,200	157,312	290,900	134,100	228,100	+74/+59
-	-	47,094	17,800	29,500	-4/-8
			1,159,900	2,001,700	+62/+52

and the shutdown point, as being extremely limited. However current profits (Table 1) reveal the flexibility of the individual firms. Moreover, only Firestone provided a detailed compliance cost estimate (considered inconsistently high by the Snell researchers)[50] yet even Firestone failed to integrate these costs into an economic model which reflects their individual flexibility. No other company even provided detailed compliance cost estimates, not to mention an analysis of their flexibility.

An analysis of the hypothetical firm constructed for the economic impact study reveals considerable flexibility.[50a] The basis for this flexibility is the relatively high rate of return on total investment (20%) and also the range of production quantities ($Q_2 \ldots Q_1$) between the break-even point (the long run break even point includes a return on investment here hypothesized to be 10%) and the shut-down point. The Average Fixed Cost of VCM was computed to be 0.61¢/lb: overhead (0.15¢) plus taxes and insurance (0.06¢) plus depreciation (0.40¢). The Average Variable Cost was computed to be 5.82¢/lb.: raw materials, ethylene (2.94¢) and chlorine (2.01¢), plus labor (0.12¢) plus utilities (0.25¢) plus maintenance (0.20¢) plus selling and administrative expense (0.30¢). The Average Total Cost equalled the Average Fixed Cost (0.61¢) plus the Average Variable Cost (5.82¢) plus a hypothetical return on capital of 10% (0.49¢) to continue to attract investors (6.92¢/lb). The market price of 7.41¢/lb. results in an additional 10% return on capital which is the result of the very strong demand for vinyl chloride. The increase in the average cost will of course be determined

FIGURE 1



MC = Marginal Cost
AC = Average Cost
AVC = Average Variable Cost

by the cost of compliance, data which the industry has failed to provide. However, there is a .98¢/lb. flexibility described by this analysis even assuming constant prices, which would result in production at the break even point. There is a 1.10¢/lb. flexibility in increased variable costs before shut-down would occur.

While it is hypothetically possible that during a brief period of time the price for VCM and PVC might remain unchanged, this will occur only when the market is out of adjustment. Market adjustments will prevail and the price will rise. A price rise will particularly benefit the marginal firm since the increase in the total revenue will outstrip the increase in the total variable cost for most firms.[51] The probability of a price rise is based on two considerations. First, the demand for PVC has been steadily increasing in the face of an inelastic supply.[52] Moreover, a constant rise in the demand for a product will result in momentary price increase due to the complete inelasticity of the supply curve in the short run.[53] Neither the individual firm nor the industry is capable of instantaneous reallocation and adjustment of its production resources in order to increase the supply.[54] Long run adjustments in the supply-demand relationships will occur as production is increased at existing sites or additional production facilities are constructed. However, the price will never return to its original level because there is an additional variable cost necessary to coax scarce resources away from other industries in order to expand production in the VCM industry.[55] In this case those scarce resources are chlor-

ine and ethylene.[56] Thus, this price increase in response to the rising demand increases the total revenue and thereby inducing expansion and encouraging further capital investment in the industry.

This price increase will be even more marked because of the inelasticity of the demand in VCM/PVC market, i.e. the total quantity demanded will vary within a narrow range regardless of the price. The reason for this is that in the short run, [57] vinyl chloride is a key material in many plastic products.[58] The industry testified as to vinyl chloride's unique qualities and also as to the extreme expense of searching for a viable substitute. Any substitute would require engineering modifications to integrate it into the manufacturing process.[59] Accordingly, the industry predicted a lag time of 2 or 3 years before suitable substitutes could be developed.[60] The industry would like to characterize these facts as evidence of how vital their product is to the economy while at the same time citing an economic inability to comply with federal regulations. However, this is an economically contradictory argument. It is precisely the uniqueness of the vinyl chloride material which will permit the manufacturers to pass the compliance costs downstream rather than absorbing them in a reduced profit margin. Not only is the demand for vinyl chloride inelastic, but it has increased substantially during the last five years. This fact reinforces the likelihood that vinyl chloride production will continue regardless of the proposed standard.

Market conditions will therefore result in a price increase as the market adjusts to the increased total costs. This analysis is confirmed by the economic impact study.[61] The industry claim of complete shutdown not only is unsupported by hard economic data, it is contrary to the basic economic principles involving a company's capacity to offset its increased costs by the necessary and projected increase in price.

In light of industry's spurious shutdown claims in other industries such as the automobile industry (emission control standards),[62] and the asbestos industry in relation to compliance with the 2-fiber standard,[63] the Secretary and the worker must view with well-founded suspicion the shutdown arguments advanced by vinyl chloride monomer and polymer manufacturers. In light of a recent economic impact study of pollution control expenditures which estimated only 2% or 12,000 plants would be forced to shut down due to environmental regulations, the present industry allegations should be recognized for what they are--namely an unsubstantiated "shutdown scare".[64]

ECONOMIC ANAYLSIS OF VINYL CHLORIDE EXPOSURE

Compliance costs are the inevitable consequence of any effective regulatory action. (Of course, this assumes that the regulatory action actually leads to abatement, which is not always true, to say the least.) In fact, they are necessary if an existing hazard is to be removed from the workplace. Morover, the Occupational Safety and Health Act mandates these expendi-

tures through its standard-setting and enforcement mechanisms.[65] Therefore, an analysis of economic feasibility is legally unacceptable when it concentrates entirely on "direct compliance costs" and totally ignores the requirement that no employee will suffer material impairment of health or functional capacity.[66] In the case of vinyl chloride, this non-impairment of health translates into no detectable worker exposure. Thus the economic analysis must extend to the costs of failing to implement the "no detectable exposure" standard, e.g. medical costs and lost wages; the consequences of disease and death including family loss and pain and suffering; as well as the savings which follow the implementation of the "no detectable exposure" standard. In assessing industry claims of economic infeasibility and industry close-down, it must be realized that these blanket generalizations are simply untenable, especially when publicly available data indicate that the market is capable of responding flexibly to a wide range of changing conditions and variable resources.

A. Direct Costs

1. Comparative Advantage of Age and Size.

Industry alleges that the older manufacturing plants require more extensive modifications in order to comply with the new standard because the technological processes used in the older plants create a higher danger of vinyl chloride leakage. Information describing precisely how many plants are sufficiently outdated to require discontinuation rather than modification as a result of

federal standard-setting was not provided by the industry. Evidence was presented which shows the comparative advantage which will accrue to the firms with newer production methods.[67] However, the comparative disadvantage of the older plants is certainly not statutorily protected. In light of the fact that the company's existence is not guaranteed under the Act,[68] it is certainly clear that the older plant, constituting a less economically efficient operation in the market place, has no basis to complain that it is disadvantaged. It is difficult, in fact, to predict with any certainty whether this comparative advantage of the modern plants will be significant in the short run or whether it will remain so in the long run.

Polyvinyl chloride compounds are frequently produced in small quantities to fill particularized specifications.[69] For the smaller custom orders the mixing of batches of different polyvinyl compounds necessitates repeated vessel cleaning which eliminates the economies of scale enjoyed by the new plants with their large reacter vessels. The smaller and older plants could potentially be used effectively to fill these special orders.[70] However assuming that such a production shift to specialized compounds is impossible, some of the older plants which have been in existence since the 1940's are no longer cost-competitive and will become obsolete in a few years anyway.[71] The effect of the federal regulations in such cases would be merely to hasten the departure of the plants from the market place.[72] But this result is inconsistent with the record demonstrating the

economic strength of the firms in the vinyl chloride industry and their willingness to invest.[73] This indicates that the firms will seek to replace or modernize their obsolete plants, thereby becoming cost-competitive rather than withdrawing altogether from this profitable market.

2. Comparative Advantage of Location

More noteworthy in industry trends than the increase in plant size is their location. In order to take advantage of the possibility of natural ventilation provided by the warmer climates of the Southwest, some companies are building their new plants in this region. If natural ventilation is authorized as an abatement technique for reducing vinyl chloride concentrations under the new standard,[74] then the firms which have recently expanded in the Southwest as compared to the closed and smaller plants of the Northeast will enjoy a comparative advantage at least as to the alternative of open-air ventilation.

Once again we must emphasize that whether one firm or another gains a comparative advantage is of no relevance to the decision-making process of the Secretary. As was stated in the Industrial Union Dep't case:

> ...It would appear to be consistent with the purposes of the Act to envisage the economic demise of an employer who has lagged behind the rest of the industry in protecting the health and safety of employees and is consequently financially unable to comply with new standards as quickly as other employers.[75]

In addition, the importance of the geographic variable should be minimized in light of industry testimony to the effect

that it would be a mistake to place particular emphasis on this factor alone because there are so many factors to be considered in plant construction.[76] Certainly whatever the advantages of open-air dispersal as a solution to the problem of vinyl chloride concentrations in the immediate workplace environment these advantages may be minimized by the costs of compliance with any new ambient air or emission level standards for vinyl chloride promulgated by the Environmental Protection Agency under the Clean Air Act.[77] Moreover the expanded use of open-air ventilation thereby increasing the levels of vinyl chloride in the surrounding community may result in greater economic costs to the society by virtue of increased cancer incidence among the community residents.[78]

3. Irrelevance of Profit Margins in Standard-Setting.

From an economic standpoint compliance costs will not cut into industry profit margins in the long run because of long run price adjustments and factor shifts. Of course, in the short run some costs will be absorbed, but it would be improper to rely on short run dislocations as an indication of the long run market conditions. It is also important to note that industry's insistence on the inelasticity of demand supports the conclusion that costs will be passed on and not absorbed. Moreover, the uniqueness of the polyvinyl chloride resin and its products which will permit the industry to pass the compliance costs downstream rather than absorbing the reduced profits in the shortrun and eventual industry shutdown in the long run.

From a legal standpoint, the adverse effect on industry

profits from compliance with occupational safety and health standards is irrelevant.[79] The Industrial Union Dep't case states clearly that "standards may be economically feasible even though, from the standpoint of employers, they are financially burdensome and affect profit margins adversely".[80] The market determines profit margins -- there is no definable level for what constitutes a fair profit that is legally relevant to these proceedings. The concept of profit margins is an economic one and it is inapporpriate to consider the question in a standard-setting process.

4. Health Standards Must Override Corporate Investment Decisions.

In any case, profit margin does not determine the survival of the entire vinyl chloride industry, but only the amount of investment made in a single firm. A firm derives capital for investment from three sources: (1) its own resources, frequently by reinvesting its own profits; (2) the parent company, if there is one; and (3) outside sources, which will be determined by publicly reported earnings. The most notable feature of the vinyl chloride industry is that almost all of the manufacturers are divisions of a larger parent company. For example, Hooker Chemical Corp. is a division of Occidental Petroleum with total assets in excess of $2.8 billion[81] and profits for the first six months of 1974 up 403%. The Dow Chemical Company U.S.A. with total assets in excess of $3.8 billion[82] has had a sales increase of 61% in the first six months of 1974 with profits up 90% for that period. Its profits are up 124% for the second quarter

in 1974 over the same quarter in 1973. Dow Chemical Company U.S.A. is part of Dow Chemical Company, a multinational corporation. In the case of American Chemical Company, the corporation is jointly owned by ARCO a division of Atlantic-Richfield and Stauffer Chemicals.[83] The combined assets of these corporations exceeds $4.6 billion in 1973 and Atlantic-Richfield boasts an increase of profits for the first six months of 1974 at 197%. Similar ownership status exist for Firestone Chemical Division of Firestone Tire & Rubber Company and the B.F. Goodrich Chemical Company of B.F. Goodrich Tire and Rubber Company. The economic significance of these corporate arrangements is that the investment can be drawn from the earnings of other divisions of the same corporation without having to rely on outside capital if outside investors hesitate to finance the initial modifications. As evidence of the reinvestment policy to draw on full corporate resources the chemical industry is presently boosting capital expenditures markedly, signifying full confidence in its own earning potential.[84] Because the present investment comes principally from within the firm, or at least from within the parent company, the temporarily reduced margin of profit--if there is a reduction at all--will be absorbed by the industry itself, not by the investment market. Typically, of course, the firms will re-invest their own capital.

The companies' position reduces to the argument that despite their vast financial resources, they will reduce their capital if the government effectively regulates the industry. This is just another example of blackmail, and seeks to place the en-

tire authority for determining health and safety requirements under the voluntary control of the firm itself--a result which is totally impermissible under OSHA. Congress completely removed this decision-making authority from industry and delegated it to the Secretary of Labor.[85] The regulation of vinyl chloride is not a matter subject to the arbitrary judgment of the private sector. Rather, the control of this serious hazard is a matter to be exclusively exercised by the government acting in the public interest.

From the industry record of a high level of reinvestment in vinyl chloride operations, their claims of economic feasibility sound like a simple effort to avoid compliance costs. The case of the marginal firm in the industry--if there are any--presents a somewhat different situation because it will have relatively less access to outside investment money and little internal financing. However, from a maximum efficienty perspective the protection of the marginal firm is pointless since the Labor Department will be perpetuating an operation which is a serious health hazard as well as inefficient and non-competitive. Ultimately, the investment choice should be a market test of viability with the regulations serving simply to internalize occupational health costs.

If reduced investment does occur as industry threatens, it will probably occur in those firms which return the least amount of profit per dollar invested--the smaller and older production plants. Should any of these plants shutdown as industry has alleged will occur, then the selectivity of that shutdown will be

based on already manifested occupational health hazard. Thus where difficulty is encountered in controlling the hazard, economic efficiency will require those firms to shutdown. In essence the regulation serves as an economic quarantine order issued to control an unabated health hazard.

B. The Arthur D. Little Diversion

The Arthur D. Little study presented to the Department of Labor by the Society of the Plastics Industry failed completely to provide any meaningful data with respect to economic infeasibility. Arthur D. Little was content to accept without any substantiation industry claims of industry and firm shutdown.

The highly publicized Arthur D. Little "economic impact" analysis ignored entirely the major economic issue--the actual effect of the regulations on the industry. It concentrated with unequalled myopia on the supposed economic impact on the total economy if the VCM/PVC industry shut down--a conclusion it accepted unquestioningly. Not only does the study fail to elucidate the problem, it confuses the issue by diverting attention to downstream effects even then failing to support its conclusions by economic analysis. The Society of the Plastics Industry's representations, on which Arthur D. Little based its study, were nothing more than a compilation of individual firm's reports, since no independent survey was conducted and no outside expertise was utilized in making their assessments. The SPI proposal for a vinyl chloride level is merely a consensus standard and therefore necessarily a compromise position among the member firms.

C. The Social Cost of the Failure to Regulate

In order to make a competent judgment on the affects of occupational health standards in the vinyl chloride industry, it is necessary not only to measure the costs of compliance, but also the cost-savings which accrue to the employer, the worker, and the Nation as a result of the worker's improved health. In terms of methodology, any mode of analysis which ignores these cost savings is grossly inadequate and must be rejected as a decision-making tool. In terms of statutory purpose, Congress explicitly emphasized the overriding importance of worker health by passing the Occupational Safety and Health Act of 1970. A failure to identify the values associated with worker health, although difficult to quantify, is inconsistent with the statutory purpose of the Act.

1. Quantification

The total impact of federal regulations would be more easily determined if the value of worker health could be quantified. However, the dollar is a dangerously imperfect unit to use when measuring the quality of human health and human values. The fact that health and life values cannot be precisely quantified does not imply that they may be ignored. To the contrary, every effort must be made to account for these costs, though obviously the value assigned--monetary or otherwise--will be conservative in light of the intrinsic importance of health and well-being to the individual.[86]

Of course, values can be assigned as first approximations simply to enter the value into the calculus of the problem.[87] For instance, it has been suggested in the environmental field that a value be assigned to a river in its fresh and free-flowing state, thereby permitting a comparison of that value with competing industrial or recreational uses.[88] These are positive values, that is, they value damage in terms of the damage, not merely in terms of restoration or abatement expenditure.

Economic impact must stress the cost to the worker, not the spurious industry claims. The consequence of a failure to regulate vinyl chloride is clear--worker death among the exposed working population. When dealing with the risk of death involving large working populations, the issue is not probability of death for the individual worker, but rather the inevitability of death and disease for a percentage of the population. The question of preservation of life should hardly be a matter of choice requiring long deliberation, as Congress determined in enacting the Occupational Safety and Health Act. And certainly it is unacceptable to allow the decision-making to remain in the self-interested control of industrial management, or even to be susceptible to their influence.[89] The decision to introduce a carcinogen such as vinyl chloride into the production process has been paid for by the sacrifice of human lives and by the death of individuals who, as a rule, had no part in such a decision.

Eliminating the vinyl chloride hazard will lengthen the worker's life, a value which can be measured in terms of man years

or life years.[90] For example, a worker who had a life expectancy of 72 years and dies at the age of 48 has suffered a loss of 24 life years. Although such raw data hardly conveys the physical, emotional and economic catastrophe associated with cancer, it does permit some computation of life values in the society, and does recognize the positive value of living to the individual, rather than merely the cost aspects in relation to his or her employer and family. In terms of cost to the industry of a deceased worker, the loss is measured by the value of experience which that worker would have contributed in the workplace, the administrative costs of reporting the disease and employing a new person, and the training costs for a replacement for the victim.

The loss of life due to angiosarcoma cannot be fully quantified in terms of production loss in the workplace or income loss to the family. There is an intrinsic value to human existence which monetary sums cannot quantify and which can be measured in terms of life years.[91] The twenty-four vinyl chloride victims represent a loss of productive capability equal to the number of years they would have continued to work had they not died.[92] Since their average age at death was forty-eight, the total production loss, assuming retirement at age sixty-five, is 408 work-years. Assuming a normal life expectancy of seventy years, the total loss of their deaths is 528 life-years. This total loss figure will be continually increasing over the life span of the presently exposed worker population. Only by en-

forcing a non-detectable standard and thereby eliminating the angiosarcoma hazard can this loss of life be stopped.

2. Health Costs Saved

The primary impact of the vinyl chloride regulations will be the abatement of the health hazard posed by exposure to a carcinogen. The health savings are enormous in terms of (1) hospitalization and (2) alleviating the burden of disease and death costs on the worker's family as well as the employer.

A study by Cancer Care, Inc., and the National Cancer Foundation computed median medical expenses for cancer to total $19,054 per patient, whereas the median income of the workers suffering such a burden was only $8,000.[93] It is clear that the total impact--not only economic, but also psychological and social--on the individual who incurs a terminal cancer illness, as well as on his family, is crushing.[94] There has never been a justification advanced for externalizing the costs of vinyl chloride-induced angiosarcoma to the worker and his family, rather than internalizing the cost to the industry which has placed the worker at risk. In considering the employer's responsibility for the hazards created at the worksite, the Court in Industrial Union Dep't, AFL-CIO v. Hodgson stated:

> There can be no question that OSHA represents a decision to require safeguards for the health of employees even if such measures substantially increase production costs.
>
> ...It would appear to be consistent with the purposes of the Act to envisage the economic demise of an employer who has lagged behind the rest of the industry in protecting the health and safety of employees and is consequently financially un-

able to comply with new standards as quickly as other employers.[95]

3. Impact on the Family

To the extent that workmen's compensation does not reimburse the family for the full amount of the lost earning power of the worker, these earnings will be lost completely. By enforcing a non-detectable standard, the worklife expectancy will be lengthened. This factor is especially noteworthy in light of the fact that the average age of the angiosarcoma victims has been 48 years, which is the period during which the worker enjoys near-maximum income production.[96] The problem of lost wages is intensified by the prolonged period preceding death during which the family suffers reduced income due to the number of hours its members must spend caring for their ill parent and spouse.

In the long run, of course, the family members will seek their own employment to replace the deceased's income flow. However, where the deceased worker was male, the widow will be handicapped in her search for a job with a salary commensurate with her husband's because of her frequent lack of employment experience. She will also be victimized by discrimination in hiring and salary levels.[97]

4. Insurance Costs Reduced

To the extent that the hospital and medical costs are covered by workmen's compensation payments or private insurance, claims against these policies will also be eliminated. In the case of Earl Parks, an angiosarcoma victim at the Goodrich-Louisville operation, the workmen's compensation benefits totalled almost $6,000, which is certainly a conservative indicator of the

cost magnitudes which the companies will have to bear in this area.[98] The widow of Rayfield Sims, another angiosarcoma victim, has received $13,148 in benefits.[99] In fact, the Social Security Administration reports that employers paid well over four billion dollars in workmen's compensation benefits during 1973, and other estimates ranger higher.[100]

Simultaneously with the reduction in litigated claims there will be a reduction in the associated workmen's compensation premiums as the result of a vinyl chloride standard which actually protectsworkers' health. Parenthetically, it is clear that these insurance premiums will increase substantially in 1974 and 1975 as the insurers act on the carcinogenic risk created by employers.[101] Only by the enforcement of a non-detectable standard can this increase be minimized and eventually eliminated. Among other reduced costs will be the death benefits frequently included under workmen's compensation and potential tort liability (negligence and wrongful death) which would expose the employer to increased general damages including recovery for pain and suffering. The reduction and elimination of these awards has prospects for reduced insurance premiums. As an indication of the added cost of simply processing these payments, the National Safety Council reports that employers spent $1.9 billion on administrative costs of insurance alone.[102] Moreover, the National Safety Council estimates that industry spends $6.4 billion "in lost wages for workers who weren't injured but who stopped to help, conducted investigations, or wrote accident reports".[103]

5. Productivity Savings

The regulations will promote a general efficiency within the industry: the improved health of the workers will result in a labor productivity increase, and the technological advances spurred by the need for engineering controls will lead to an increasein productivity per unit of input.

From a perspective of transitional dislocation, there also will be a benefit to society. If, as industry claims, there will be a substantial increase in the number of employees needed to monitor the emission levels, operate the new engineering controls, and perform the record-keeping operations, then employment will rise significantly. Firestone has claimed that it will need to double its work force in order to comply with the no detectable exposure standard.[104] There will also be a substantial increase in production in these sections providing engineering services, equipment, protective clothing and breathing apparatuses.

The effect of vinyl chloride standards will be to improve the health of the working population employed in vinyl chloride manufacturing and processing. As a result, the consumption of medical services by the victims, for example physician and hospital care, will be significantly reduced. In the long run the resources which would have been used in this medical or caretaking role, i.e., the treatment and cure of acroosteolysis, angiosarcoma and other vinyl chloride induced diseases, will shift into another sector of the economy. Rather than utilizing scarce resources to correct the damage which industrial production

has caused, these resources are freed for a more positive economic role. Undoubtedly some of these resources will be directed toward preventing worker exposure. The saving from these reduced medical and custodial costs is a direct and important consequence of a standard prescribing no detectable exposure.

CONCLUSION

The Health Research Group renews its fundamental objection to the consideration of economics in any determination of feasibility. However, assuming for the sake of argument the legality of economic considerations under the Occupational Safety and Health Act, the industry has failed to sustain its basic burden of proof with respect to economic infeasibility.

The contents of the economic impact study prepared by Foster D. Snell, Inc. emphasize the failure of the industry to produce detailed and relevant economic data to support any of its claims. Moreover, the Snell study negates rather than confirms the industry's claims of economic infeasibility with respect to polymerization plants. Unfortunately the study was not scrutinizing enough when it simply accepted without any explanation industry claims of technological infeasibility with respect to synthesis plants. Furthermore, certain techniques resulted in the overestimation of compliance costs, the underestimation of industry's capability to comply, and the total neglect of certain basic elements in the economic formula such as health costs and the savings of preventive medicine.

Congress emphasized its choice of occupational health over corporate profits when it prefaced the Occupational Safety and Health Act with the following finding, "The Congress finds that personal injuries and illnesses arising out of work situations impose a substantial burden upon and hindrence to, interstate commerce in terms of lost production, wage loss, medical expenses,

and disability compensation payments".[105] The report of the House of Representatives' Committee on Education and Labor concluded, "...Even the price of one life is too expensive when a meaningful occupational safety and health law could save many lives".[106]

In summary, these proceedings have revealed only the bankruptcy of industry's factual case, not its corporate treasuries. Though human life is perhaps without any precise economic value, it is not valueless. Certainly the term "feasibility" was not included in the Occupational Safety and Health Act to justify the pricing of vague generalities, self-serving assumptions and unsubstantiated analyses above the value of human life.

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FOOTNOTES

1. 29 U.S.C. § 655(b)(5)(1970).

2. Testimony of Bertram Cottine and Andrea M. Hricko, Staff Associates, Health Research Group, July 9, 1974, Tr. Exh. #39n.

3. Industrial Union Dep't, AFL-CIO v. Hodgson,--- F.2d ---, No. 72-1713 (D.C. Cir., decided April 15, 1974), petition for rehearing denied (June 27, 1974).

4. Id., slip. opin. at 19, 20-21.

5. Id.

6. Id. at 20.

7. Id.

8. S. Rep. No. 91-1282, 90th Cong., 2d Sess. 4 (1970).

9. 15 U.S.C. § 636(b)(6)(1970).

10. 29 U.S.C. §§ 655(b)(6), 655(d)(1970).

11. Testimony of Jerome H. Heckman, General Counsel, Society of the Plastic Industry, June 26, 1974, Tr. , Exh. #20c. at 2.

12. E.g., Synthetic Organic Chemical Manufacturers Ass'n. v. Brennan, --- F.2d ---,No. 74-1129 (3d Cir., decided August 26, 1974) slip. opin. at 7-9 (determination of human carcinogenicity).

13. 29 U.S.C. § 664 (1970); H.R.Rep.No.91-1291,91st Cong.,2d Sess. 40(1970).

14. See generally C. Mc Cormick, Handbook on the Law of Evidence § 249)1954).

15. Foster D. Snell, Economic Impact Studies of the Effects of Proposed OSHA Standards for Vinyl Chloride chs. III & IV, Apps. A, B, D & E. (1974)(later cited to as Economic Impact Study).

16. Id. at I-1, Exhibit I-1.

17. Id. at V-12.

18. Id. at V-2.

19. Id. at II-1 to II-2.

20. Id. at IV-4.

21. Id. at Exhibit II-1(1).

22. Id. at Exhibit I-2.

23. The contractor accepted similar industry claims with respect to economy of a continuous polymerization process, Economic Impact Study at Exhibit C-2(6), and time requirements, Id. at V-5.

24. Id. at Exhibit C-2(5).

25. The methodology merely provides a coding system to maintain the confidentiality of trade secrets, Economic Impact Study at II-6, however it apparently was unnecessary to apply the code to any data. In light of the numerous claims of proprietary information raised during the hearing, this indicates the inaccessibility of this type of information to the contractor.

26. 29 C.F.R. § 1910.95 (1973).

27. 29 C.F.R. § 1910.93 (1973).

28. Industrial Union Dep't. AFL-CIO v. Hodgson, supra at 20.

29. Id.

30. Id. at 19.

31. H.R.Rep.No.91-1291, 91st Cong.,2d Sess. 16-18 (1970); S.Rep.No. 91-1282, 91st Cong.,2d Sess. 1,4-5,6 (1970). Compare 29 U.S.C. § 655(b)(5) with 29 U.S.C. § 655(a)(1970).

32. Economic Impact Study at App. C-2(6).

33. 39 Fed. Reg. 12342 (April 5, 1974).

34. Economic Impact Study at V-7.

35. Uniform Commercial Code § 2-706 (1962 version). See also Uniform Commercial Code §§ 1-203, 1-204, 2-712 (1962 version).

36. Economic Impact Study at V-2.

37. Id. at V-12.

38. Industrial Union Dep't, AFL-CIO v. Hodgson, supra at 20.

39. Id.

40. Id.

41. Id.

42. For a complete analysis of the strength of the companies which comprise the vinyl chloride industry see pp. 17-18 & Table I, infra.

43. See generally P. Samuelson, Economics ch. 23 (9th ed. 1973) (later cited as Economics).

44. Id. at 465. Certain of the costs of production are labeled "fixed" because they are costs incurred whether the firm produces or not. Such costs include property and franchise taxes, interest due on loans and bonds, certain overhead expenses such as watchmen's salaries, and rental payments on property and machinery. The remaining costs are called "variable" because they vary with output: wages of employees, costs of materials, administration, engineering research, quality control, etc.

45. Second Thoughts on Using PVC, Chemical Week, July 31, 1974, at 20.

46. CPI on Capital Spending: Full Speed Ahead, Chemical Week, Jan. 9, 1974, at 12.

47. Id. at 11.

48. Chemical Week, January 9, 1974.

49. Business Week, August 10, 1974, at 74-75.

50. Economic Impact Study at V-6.

50a. Id. at Exhibit IV-4.

51. Economics at 386.

52. See generally Economics at 377-384.

53. Economics at 384-386.

54. Id.

55. Id. at 385-386.

56. Chem.&Eng.News, June 3, 1974, at 24,27; Modern Plastics, May, 1974; Chem.Mktg.Rep., July 29, 1974, at 4.

57. See note 52, supra.

58. Although PVC fabricators will have little trouble complying with the proposed permanent standard, their dependency on the companies synthesizing VCM and polymerizing PVC is very high. The processors may seek substitutes for vinyl chloride as an intermediary good based not on their own compliance costs, but due to the increased manufacturers' prices.

59. In Vinyl Chloride Hearings at 1495(1974), Uniroyal stated: ...Uses and fabrication techniques have for the most part been developed to handle PVC and are not easily adapted or adapted at all, to other materials. One does not simply substitute rubber or some other plastic material without substitutional changes in skills, equipment, and capital costs.

60. The B.F. Goodrich Company, largest producers of VCM with 15% of market, estimated a 24 month lag. Vinyl Chloride Proceedings at 1150 (1974).

61. Economic Impact Study at V-7.

62.

63.

64. Council on Environmental Quality, U.S. Dep't. of Commerce & Environmental Protection Agency, The Economic Impact of Pollution Control: A Summary of Recent Studies 10 (1972) (later cited as Economic Impact of Pollution Control).

65. 29 U.S.C. §§ 655, 657, 658, 659 (1970).

66. 29 U.S.C. § 655(b)(5) (1970).

67. U.S. Dep't. of Labor Official Report of Proceedings before the Occupational Safety and Health Administration: In the matter of Proposed Permanent Standard for Occupational Exposure to Vinyl Chloride 1524-25(1974). (hereinafter cited as Vinyl Chloride Hearings.) For a detailed comparison of plant costs, see Exhibit 48C at 138.

68. Industrial Union Dep't AFL-CIO v. Hodgson, supra at 20.

69.

69. Vinyl Chloride Hearings at 1141 (1974).

70. The contractor concluded that the use of small reactors is expected to continue in the long run, but only for the production of specialty resins, Economic Impact Study at III-7.

71. For a comparison of modification costs by different age plants, see note 5, supra.

72. A similar conclusion was drawn in the pollution control field. Economic Impact of Pollution Control 9 (1972).

73. CPI on Capital Spending, Full Speed Ahead, Chemical Week, January 9, 1974 at 12. See generally Table 1.

74. Vinyl Chloride Hearings at 1324 (1974):
...The American Chemical Society is concerned that increased reliance on ventilation methods as dealt with in § (1)(6)(n)

of the standard does not ameliorate the problem of the potential hazard to the public, and therefore recommends adsorption and scrubbing techniques to reduce the level of vinyl chloride. As an alternative to open-air ventilation, Calgon Corporation discussed the hydrocarbon filter as a component of an effective recovery system. Vinyl Chloride Hearings at 1895 (1974).

75. Industrial Union Dep't, AFL-CIO v. Hodgson, supra at 20.

76. Vinyl Chloride Hearings at 1094 (1974).

77. The interrelation of the cost of complying with both the Clean Air Act and occupational safety standards is evidenced by the Snell study remark that Firestone failed even to differentiate between the two in its compliance cost estimates. Economic Impact Study at V-6. Chem. & Mktg. Rep., June 17, 1974 at 4,23.

78. Bridboard, Paper Presented to New York Academy of Sciences, May 11, 1974; Schweitzer, The Environmental Threat From Vinyl Chloride Beyond the Work Place, New York Academy of Sciences, May 11, 1974. See generally Petition of Health Research Group to suspend Pesticide Products With Vinyl Chloride Propellants Before Environmental Protection Agency 5-7 (filed Feb. 21, 1974); Testimony of Bertram R. Cottine & Andrea M. Hricko, Staff Associates, Health Reserach Group, July 9, 1974, Exh. #39a, at 12-13.

79. See text accompanying note 2.

80. Slip opin. at 20.

81. Fortune, May, 1974, at 232.

82. Id.

83. Stanford Research Inst., Directory of Chemical Producers: USA 24 (1972 ed.).

84. See pp. 17-18, supra.

85. See note 31, supra.

86. This concept of intrinsic undervaluation reaches its logical end in the merit-good: that is, the consumption of some goods is conceived to be of such overriding significance to the well-being of society that the consumption should not be dependent on income. An example is public health. Krutilla and Knetsch, Outdoor Recreation Economics, 389 Annals 63, 65-67 (1970). Health, as a merit-good, does receive an assigned cost value--the amount of money the industry or government spends to protect the health of its workers or its citizens--as well as a benefit value--the improvement in worker health.

87. For a possible appraisal of the usefulness of quantification, see Boulding, Economics as a Moral Science, 59 Am. Econ. Rev. 1, 5 (1969).

88. Tiebhafsky, An Alternative Approach, 13 Natural Resources 621, 623 nn. 30 & 31.

89. As an example of the abuse to which the vinyl chloride worker has been subjected, we need only point to the industry's consistent failure to inform its employees of the potentially fatal results of exposure, information which it has possessed since at least 1970, P.L. Viola, Carcinogenic Effect of Vinyl Chloride, presented at the Tenth International Cancer Congress, Houston, Texas, May 22-29, 1970; Mastronmatteo, Fisher, Christie, and Danziger, Acute Inhalation Toxicity of Vinyl Chloride to Laboratory Animals, 21, Am. Ind. Hygiene Assoc. J. 394-98 (October, 1960).

90. Murray and Axtell, 52 J. Nat'l. Cancer Inst. 1 (1974).

91. For a computation using this type of quantifying unit, see Murray and Axtell, 52 J. Nat'l. Cancer Inst. 1 (1974). The total number of person-years lost due to cancer is over 5 million, as computed by Murray and Axtell.

92. The total number of vinyl chloride-induced deaths has now risen to 24.

93. Statement of Industrial Union Dep't, AFL-CIO, Ex. No. . In another study, Dr. Thomas Hodgson, Jr., of HEW's Social Security Administration itemized these "Estimated Direct Costs" of cancer, the total of which was $3.4 billion: hospital care, $1.9 billion; nursing home care, $108 million; physician's services, $.55 billion; drugs, $52 million; nursing, $42 million; research, $276 million; training, $31 million; other, $51 million; construction of facilities, $220 million; administration, $134 million. The Cost of Cancer: A Working Draft, prepared by Ronald Ruskan, Industrial Union Department, AFL-CIO.

94. Facing Death, The Hastings Center Studies (May, 1974) at 2.

95. Slip. opin. at 19,20.

96. The census Bureau reports that for 1973 the income for males in the 45-54 age group was $12,756, well above the average median income for all age groups of $11,468, and a close second to the 35-44 age group, which was $12,909. U.S. Dep't of Commerce, Census Bureau, Money Income in 1973 of Families and Persons in the United States, (P-60 No.93).

97. D. Sommers, Occupational Rankings for Men and Women by Earnings, Monthly Labor Review, August 1974, at 47.

98. In the Matter of Earl D. Parks, Sr., Settlement Agreements (Ky. Workmen's Comp. Comm'n. 1964,1971).

99. Statement of Industrial Union Dep't, AFL-CIO, at 22.

100. D. B. Kalis, Update on the Cost of OSHA Compliance, Occupational Hazards, August, 1974, at 44.

101. The compulation of workmen's compensation premiums varies between state, but it is clear that the premiums will rise as the litigated claims payments increase. This will occur at the end of the statutorily prescribed term for which the coverage runs.

102. See note 96, supra.

103. See note 90, supra.

104. Vinyl Chloride Hearings, Exhibit 49C, at 142.

105. 29 U.S.C. § 651(a)(1970), also S. Rep. No. 91-1282, 91st Cong., 2d Sess. 2(1970); H.R. Rep. No. 91-1291, 91st Cong., 2d Sess. 14 (1970).

106. H.R. Rep. No. 91-1291, 91st Cong., 2d Sess. 35(1970).

85.40

DRAFT FINAL REPORT

ECONOMIC IMPACT STUDIES OF THE EFFECTS OF PROPOSED OSHA STANDARDS FOR VINYL CHLORIDE

Contract No. L/A 74-167

Mr. James Kallenborn
Acting Director of Planning, Evaluation and Research
OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

U. S. DEPARTMENT OF LABOR

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September 13, 1974

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September 13, 1974

Mr. James Kallenborn
Acting Director of Planning, Evaluation and Research
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Re: Contract No. L/A 74-167

Dear Mr. Kallenborn:

The following is the Draft Final Report being submitted for insertion into the Vinyl Chloride Hearing Transcripts. The Draft Final Report supersedes the Preliminary Report and includes refinement of the Preliminary Report as well as incorporation of limited new information.

This Draft Final Report presents Snell's evaluation of the technical feasibility and resulting costs of compliance with various target levels of Vinyl Chloride exposure. The work includes data on monitoring and personal protective equipment, and worker medical surveillance.

The report is organized into two sections:

- Analysis of the findings and conclusions
- Supporting Appendices

We would like to thank you for the cooperation provided by you and your associates in this study. Please do not hesitate to call should you have any questions about this report.

Sincerely,

FOSTER D. SNELL, Inc.,

Joseph Nemec, Jr., Ph.D.
Vice President

mjs

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I. INTRODUCTION

I. INTRODUCTION

This chapter presents the background of the economic impact study of the proposed OSHA standards for vinyl chloride, the study scope and the organization of the report.

1. SNELL'S ASSIGNMENT WAS TO ASSESS THE ECONOMIC IMPACTS RESULTING FROM THE COST TO INDUSTRY FOR MEETING ALTERNATE STANDARDS FOR WORKER EXPOSURE TO VINYL CHLORIDE MONOMER (VCM) IN THE VCM AND POLYVINYL CHLORIDE (PVC) MANUFACTURING INDUSTRIES

On January 22, 1974 the Occupational Safety and Health Administration (OSHA) was informed by the National Institute for Occupational Safety and Health (NIOSH) that the B.F. Goodrich Chemical Company reported the deaths of several of its employees from a rare liver cancer (angiosarcoma) may have been occupationally related. As a result of this information, subsequent epidemiological studies and a fact-finding hearing, an Emergency Temporary Standard (ETS) was promulaged by OSHA on April 5, 1974, detailing preliminary regulations on worker exposure to VCM (50 ppm ceiling exposure limit).

As required by law, six months after the issuance of an ETS a permanent standard must be formulated and approved. Therefore, on May 10, 1974 OSHA published a proposed permanent standard which included "no-detectable limit".

To aid OSHA in carrying out its standard setting mandate Snell was assigned to prepare this report dealing with assessing the economic impacts of alternate standards for worker exposure to VCM in the VCM and PVC manufacturing industries. The alternate standards investigated are:

- 50 ppm ceiling
- 25 ppm ceiling
- 25 ppm 8-hour time weighted average (TWA) with a 40 ppm ceiling
- lower TWA(s) with a ceiling
- "no-detectable" proposed permanent standard

The study is limited to U.S. production of VCM and PVC.

Exhibit I-1, on the following page, is a summary of the scope of the Snell study.

EXHIBIT I-1
U. S. Department of Labor/Occupational Safety and Health Administration
THE SCOPE OF THE SNELL STUDY

Primary Emphasis

- Assess the economic impact of VCM regulation on VCM and PVC manufacturing only
- Concentrate on PVC manufacture (approximately 80% of level of effort)
- Investigate the following alternate standards
  - 50 ppm ceiling
  - 25 ppm ceiling
  - 25 ppm TWA[2] with 40 ppm ceiling
  - lower TWA(s) with ceiling
  - 'no detectable' level
- Emphasize key regulatory considerations
  - engineering and work practices primarily
  - use of personal protective equipment
  - environmental and personal monitoring
  - assembling of exposure data
  - residual monomer levels in PVC

Secondary Requirements

- Include a study of VCM manufacture (approximately 20% of level of effort)
- Include secondary regulatory considerations[1]
  - medical surveillance costs
  - record keeping costs
  - covered workers
  - regulated areas

Deliverables

- Deliver preliminary report on the 50 ppm, 25 ppm and "no detectable" cases in 7 weeks starting on July 1, 1974 on 23 August 1974
- Present draft final report in 11 weeks (13 September 1974)
- Key deliverables are
  - estimates of the time table required in each of these evaluations for effective implementation
    - .. in the near-term, 6 months to one year
    - .. in the longer-term, 2 years or more
  - estimates of the costs of achieving the various levels of VCM controls evaluated
  - assessment of economic impact on the basis of technical feasibility, timing and costs

(1) Other regulatory considerations include, for example, emergency situations and signs and labels, but were not included in the scope of Snell's work. All the regulatory considerations assigned for study are listed in the Exhibit. The work scope did not include study of PVC substitutes or evaluation of economic impacts outside the VCM and PVC sectors.

(2) TWA = Time weighted average

2. THE REPORT IS ORGANIZED INTO TWO PARTS

The report conclusions and recommendations are presented first supported by detailed appendices.

(1) The First Part Of The Report Represents The Findings Of Economic Impact Together With Recommendations

Part One includes the following outputs:

- Chapter I - Introduction. This chapter summarizes the problem, the scope of the study and the organization of the study.

- Chapter II - Methodology. This chapter presents the Snell study methodology.

- Chpater III - Industry Structure. This chapter presents data on:

  - members of the VCM and PVC producing industries;
  - location of plants;
  - marketing and base-line economic data.

- Chapter IV - The Technology of the Industry. This chapter describes the processes of VCM and PVC and includes:

  - process description and flow diagrams for each major process;
  - representative operating procedures.

- Chapter V - Findings and Economic Analysis. This chapter details the major findings and economic analysis emphasizing technical feasibility, timing, and costs based on aggregating individual company data to the industry levels as a function of various VCM levels.

(2) The Second Part Of The Report Presents Detailed Study Documentation (Appendices)

This part of the report is comprised of eight appendices and supports the material in Part One.

- Appendix A - Detailed Process Description and Procedures
- Appendix B - Exposure Data For Polyvinyl Chloride (PVC) and Vinyl Chloride (VCM) Plants
- Appendix C - Economic Details
- Appendix D - Personal Protective Equipment and Hygiene
- Appendix E - Monitoring Equipment
- Appendix F - Medical Surveillance of Employees
- Appendix G - Safety Awareness Programs
- Appendix H - NIOSH Recommended Occupational Health Standard for the Manufacture of Synthetic Polymer from Vinyl Chloride.

* * * * *

This chapter presented the scope of the study and organization of this report. The following chapter details the methodology used by Snell to carry out the study.

II. METHODOLOGY

II. METHODOLOGY

The Final Report supersedes the Preliminary Report. The timing of the project was such that on August 23, 1974, seven weeks from the start of the study, the Preliminary Report was submitted to USDOL/ OSHA for inclusion into the Hearing Record for comments. The Preliminary Report featured:

- fact-finding, such as field visits and telephone interviews including recontacting of parties for data clarification;
- preliminary analysis of regulatory scenarios.

The Final Report represents refinement of the Preliminary Report as well as inclusion of limited additional information. The draft of the Final Report was timed for September 13, 1974 by the end of the eleventh week of the study.

The methodology used by Snell in fulfilling the work requirement was to perform the study in several major tasks described below. All exhibits are presented at the conclusion of the text of this chapter.

1. PLANT AND INDUSTRY VISITS WERE A PRINCIPAL MEANS OF INFORMATION GATHERING

- During the course of the investigation, Snell team members made 29 industry visits. The vinyl chloride and polyvinyl chloride industries consist of 30 producers and 53 plants. These visits involved either day long technical discussions in their engineering and production offices or detailed plant tours.
- Exhibit II-1 presents the plants, location and purposes of these trips. These trips were comprised of:

- 24 plant visits

  .. 16 polyvinyl chloride plants representing 41% of the polyvinyl chloride plants

  .. 8 vinyl chloride plants representing 53% of the vinyl chloride plants

- 8 visits to corporate engineering offices

2. INDUSTRY RELATED ORGANIZATIONS, GOVERNMENTAL AGENCIES, EQUIPMENT MANUFACTURERS, AND SPECIALISTS WERE VISITED TO SUPPLEMENT INFORMATION OBTAINED FROM PLANT VISITS

   . In order to gain a broader view of the technical feasibility and necessary costs, personal visits were made to recognized experts in the areas covered by the study.

   . Exhibit II-1 details the organizations, governmental agencies, and equipment manufacturers visited and the types of information obtained. These visits included:

   - 4 visits to government agencies
   - 3 visits to industry organizations
   - 4 visits to equipment manufacturers or technical specialists

3. A TELEPHONE SURVEY WAS CONDUCTED OF MANUFACTURERS OF MONITORING EQUIPMENT, RESPIRATORY DEVICES, PERSONAL PROTECTIVE EQUIPMENT AND PROCESS EQUIPMENT

   . The purpose of this task was to obtain detailed information covering costs, availability, and technology. Information was obtained both directly through the telephone survey and the brochures and catalogues sent to Snell as a result of the conversations.

- Exhibit II-3 details the manufacturers interviewed during the telephone survey. Calls were made to:

  - 13 monitoring equipment manufacturers
  - 7 manufacturers of respiratory equipment
  - 6 producers of protective clothing
  - 7 processing equipment manufacturers

4. THE SNELL INFORMATION CENTER STAFF CONDUCTED A LITERATURE SURVEY TO IDENTIFY AND OBTAIN BACKGROUND INFORMATION ON AREAS RELEVANT TO THIS STUDY

- To obtain an overview of manufacturing processes, pollution problems, marketing, end-use products, and possible protective devices, etc., a survey of the following journals was performed:

  - Hydrocarbon Processing - 15 years
  - Modern Plastics - 5 years
  - Chemical Marketing Reporter - 3 years
  - Chemical and Engineering News - 3 years
  - Chemical Engineering - 5 years
  - European Chemical News - 3 years

- Standard chemical reference texts such as the Encyclopedia of Polymer Science and Technology and the Kirk-Othmer Encyclopedia of Chemical Technology were also researched to obtain more general information.

- Chemical Marketing Abstracts and Chemical Economics Handbook were used for basic industrial facts.

5. THE STUDY METHODOLOGY EMPHASIZED THE PARAMETERS DEFINED IN EXHIBIT I-1, IN THE INTRODUCTION CHAPTER

The methodology described in the above points was employed to determine and define the scope of the following parameters:

- Profiling of industry structure and processes
- Definition of the number of workers potentially exposed to VCM considering
  - job description
  - unit operation
  - potential exposure to VCM levels
- Determination of costs and means of controlling exposure levels through engineering controls and improved work practices with particular attention to:
  - "buttoning-up" of plants
  - ventilation
  - operation
  - maintenance
  - process improvements, such as reducing free monomer levels in the polymer
- Investigation of further methods and costs of protection through the use of personal protective equipment beyond controlling exposure through engineering and work practices

- Development of a technical and economic information base for personal and area monitoring and leak determination equipment

- Isolation of information regarding:

  - medical surveillance costs
  - record keeping costs
  - covered workers
  - regulated areas

- Detailed methodology is presented as footnotes to exhibits, textual reference or material in the appendices

6. AS DIRECTED BY OSHA THE STUDY DEALT PRIMARILY WITH PVC PRODUCTION

Approximately 80% of the level of effort was devoted to PVC production. Discussion emphasis in subsequent chapters reflects this.

7. WORK AFTER THE PRELIMINARY REPORT FOCUSED ON THE FURTHER ANALYSIS OF VCM LEVELS, AND THE RESULTANT COSTS, GENERAL DATA REFINEMENT AND FURTHER EVALUATION OF TECHNOLOGY

The principal work elements in the finalization of the Preliminary Report included:

- Study of comments from OSHA, public review and Snell's internal review of the Preliminary Report resulting in clarifications and refinement of the data
- Aggregation of individual plant exposure data from each company as well as from OSHA to develop industry profiles of average VCM levels
- Development of order-of-magnitude estimates of the potential economic impacts of meeting the PVC industry exposure limits of a 10-15 ppm VCM ceiling with a 5-10 ppm TWA
- Preparation of a case study in the PVC industry as an illustration of cost analysis approach
- Internal review of the cost analysis resulting in data refinement
- Incorporation of limited new information on technology such as stripping

8. WHERE THERE WAS A QUESTION AS TO THE POSSIBLE PROPRIETARY NATURE OF INFORMATION, DATA SOURCES WERE CODED

The elements of each coded plant designation are as follows:

- Random number only for VCM plants

- Random leading number for PVC plant

PVC Plant Capacity	PVC Plant Age	PVC Plant Siting
- S = Small, less than 100 million lbs.	- New = to 10 yrs.	- C = Cold climate
	- Int. = 11 to 20 yrs.	- W = Warm climate
- M = Medium, 100 to 200 million lbs.	- Old = Over 20 yrs.	
- L = Large, over 200 million lbs.		

For example, the code for one of the PVC plants is as follows:

52	- S	- Old	- C

- Exhibits featuring the code refer back to this page for meaning of the elements of the code

* * * * *

This chapter detailed study methodology. The chapter that follows presents the preliminary findings and conclusions.

EXHIBIT II-1(1)
USDOL/OSHA
VINYL CHLORIDE/POLYVINYL CHLORIDE
PRODUCERS VISITED AND INTERVIEWED
BY PHONE BY SNELL STAFF FOR DATA
COLLECTION

Firm or Organization Visited	Purpose of Visit
Air Products, Inc. Valley Forge, Pennsylvania	Technical and engineering data collection on PVC
Allied Chemicals, Inc. Corporate H.Q. Morristown, New Jersey	Technical and engineering data collection on VCM
American Chemical Co. Long Beach, California	Plant visit on VCM and PVC
Conoco	
. Corporate H.Q. Saddlebrook, New Jersey	Technical and engineering data collection
. Oklahoma City, Oklahoma	Plant visit on PVC
Diamond Shamrock	Technical and engineering data collection on PVC
. Corporate H.Q. Cleveland, Ohio	
. Delaware City, Delaware	Plant visit
. Deer Park, Texas	Plant visit
Dow Chemicals, USA	
. Plaquemine, Louisiana	Plant visit on VCM
. Oyster Creek Division, Freeport, Texas	Plant visit on VCM
. Texas Division, Freeport, Texas	Plant visit on VCM
Ethyl Corporation Baton Rouge, Louisiana	Plant visit on VCM
Firestone Tire & Rubber Co. Akron, Ohio	Phone interview on PVC
General Tire & Rubber Co. Ashtabula, Ohio	Plant visit on PVC

EXHIBIT II-1(2)
USDOL/OSHA

Firm or Organization Visited	Purpose of Visit
B.F. Goodrich Co.	
. Corporate H.Q. Cleveland, Ohio	Technical and engineering data collection
. Calvert City, Kentucky	Plant visit on VCM
. Long Beach, California	Plant visit on PVC
. Louisville, Kentucky	Plant visit on PVC
. Pedricktown, New Jersey	Plant visit on PVC
Goodyear Tire & Rubber Co. Niagara Falls, New York	Plant visit on PVC
Great American Chemical Co. Fitchburg, Massachusetts	Plant visit on PVC
Hooker Chemical Corp. Florence, New Jersey	Plant visit on PVC
Monsanto Springfield, Massachusetts	Phone interview on PVC
National Starch & Chemical Co. Corporate H.Q. Plainfield, New Jersey	Technical and engineering data collection on PVC
Olin-Thompson Plastics Assonet, Massachusetts	Plant visit on PVC
Pantasote Passaic, New Jersey	Plant visit on PVC
Robintech, Inc. Painesville, Ohio	Plant visit on PVC
Shell Oil Co.	
. Corporate H. Q. Houston, Texas	Technical and engineering data collection on VCM
. Deer Park, Texas	Plant visit on VCM
. Stauffer Chemicals Delaware City, Del.	Plant visit on PVC
Tenneco Burlington, New Jersey	Plant visit on PVC

EXHIBIT II-1(3)
USDOL/OSHA

Firm or Organization Visited	Purpose of Visit
Union Carbide, Inc. So. Charleston, West Virginia	Technical and engineering data collection on PVC
Uniroyal Chemical Co. Akron, Ohio	Plant visit on PVC

Source: Snell

EXHIBIT II-2
USDOL/OSHA
GOVERNMENT AGENCIES, INDUSTRY ORGANIZATIONS, AND EQUIPMENT MANUFACTURERS VISITED BY SNELL STAFF FOR DATA COLLECTION

I. Government Agencies	
U. S. Department of Labor Washington, D. C.	General data collection and attend hearings
National Institute for Occupational Safety and Health Cincinnati, Ohio	Discussion on medical, monitoring, and protective equipment
Environmental Protection Agency Washington, D. C. and Research Triangle Park, N. C.	General data collection
U. S. Department of Commerce Washington, D. C.	Industry marketing data collection
II. Industry Organizations	
Manufacturing Chemists Association New York, New York	Discussions on technical feasibility and marketing data
Organizational Resources Council, Inc. Washington, D. C.	General discussion
Society of the Plastics Industry New York, New York	Discussions on technical feasibility
III. Equipment Manufacturers, Medical Laboratories, Industrial Consultants, Etc.	
The Pfaudler Co. - Div. Sybron Corp. Rochester, New York	Discussions on polymerizers and other technical questions (sole U. S. suppliers of glass lined equipment)
Diagnostic Sciences, Inc. - Ivan K. Smith Morris Plains, New Jersey	Medical surveillance data collection
Tec-Air, Inc. - David Metal East Northport, New York	Protective equipment data collection
Human Motivation Resources - Joel D. Schaffer Morris Plains, New Jersey	Safety program data collection

Source: Snell

EXHIBIT II-3 (1)
USDOL/OSHA
FIRMS CONTACTED DURING THE SNELL TELEPHONE SURVEY OF EQUIPMENT MANUFACTURERS

I. Monitoring Equipment Manufacturers

AID
West Chester, Pennsylvania

Bacharach Instrument Co.
Pittsburgh, Pennsylvania

Bechmann Instrument
Fullerton, California

Bendix Corporation
Environmental Science Division
Baltimore, Maryland

Byron Instruments, Inc.
Raleigh, N.C.

Carle Instruments
Fullerton, California

Century Systems Corp.
Arkansas City, Kansas

Hewlett-Packard Co.
Avondale, Pennsylvania

Microchemical Specialties Co.
Berkeley, California

Perkin-Elmer
Norwalk, Connecticut

Anatole J. Sipin Co.
380 Park Avenue, S.
New York, New York

Varian Association
Palo Alto, California

Wilks Scientific
Norwalk, Connecticut

II. Respiratory Equipment Manufacturers

Bausch & Lomb
Rochester, New York

Mine Safety Appliances
Pittsburgh, Pennsylvania

Minnesota Mining & Manufacturing, Inc.
Minneapolis, Minnesota

Scott Aviatian
South Haven, Michigan

Survive-Air
Santa Ana, California

Welsh Scientific, Inc.
Providence, Rhode Island

Willson Products
Pennsylvania

III. Protective Clothing Manufacturers

Arrow Disposables, Inc.
Cincinnati, Ohio

E. I. Dupont de Nemours
Wilmington, Delaware

Durafab
Cleburne, Texas

Edmont-Wilson
Coshocton, Ohio

Mars, Inc.
Ashville, North Carolina

Uniroyal, Inc.
New York, New York

IV. Processing Equipment Manufacturers

Dresser Industries
(Compressors and Vacuum Pumps)
Connersville, Indiana

Durion Company, Inc.
(Valves and Pumps)
New York, New York

Fluid Handling System
(Viking Pumps)
Secaucus, New Jersey

GAF
(Cleaning Systems)
New York, New York

Nash Engineering Co.
(Compressors and Vacuum Pumps)
Norwalk, Connecticut

Process Pumps, Inc.
(Pumps)
Kenilworth, New Jersey

Stauffer Inc.
(Cleaning Systems)
Westport, Connecticut

Source: Snell

III. INDUSTRY STRUCTURE

III. INDUSTRY STRUCTURE

This chapter presents an overview of the structure of the U.S. vinyl chloride monomer (VCM) and polyvinyl chloride (PVC) industries. Key elements of production, prices and markets are delineated to provide a background and comparative criteria to judge the economic impact of proposed regulations on VCM and PVC manufacturing.

The chapter is divided into three sections:

- Section IIIA - Vinyl Chloride Monomer Production
- Section IIIB - Polyvinyl Chloride Production
- Section IIIC - Key Polyvinyl Chloride Markets

IIIA. VINYL CHLORIDE MONOMER

This section defines the structure of the vinyl chloride monomer (VCM) manufacturing industry.

1. NINE COMPANIES OPERATE 14 VCM PLANTS

- Exhibit III-1, on the following page, presents a profile of the VCM producers in terms of plant locations, capacities and manufacturing process. Process related factors are discussed in Chapter IV.

- Shell, Dow and Goodrich are the leading 1974-1975 producers, accounting for approximately 58% of nameplate capacity.

- Approximately 5,225 million pounds VCM are estimated to be available annually for conversion into PVC in 1974-1975, assuming no major economic impact from OSHA regulations.

- With the exception of the Goodrich plant in Calvert City, Kentucky, the U.S. VCM plants are located in warm climate areas -- Texas, Louisiana, Puerto Rico, and California. In general, the plants are open except for weather screening.

- VCM plants are generally located in or near petroleum rich areas to minimize the cost of feedstock (ethylene) transfer.

EXHIBIT III-1

USDOL/OSHA

PROFILE OF VINYL CHLORIDE PRODUCERS

Major Producer/Location		1974-1975 Nameplate Capacity[1,3] (Million Lbs.)	Process[2,3]
Allied, Geismar, La.		300	Oxychlorination
American Chemical, Watson, Calif.		170	Stauffer Oxychlorination
Conoco, Lake Charles, La.		625	Stauffer Oxychlorination
Dow, Freeport, Tex.	1,400	*180	Dow Oxychlorination
Dow, Oyster Creek, Tex.		*700	Dow Oxychlorination
Dow, Plaquemine, La.		*450	Dow Direct Chlorination
Ethyl, Baton Rouge, La.	450	*270	Direct Chlorination
Ethyl, Houston, Tex.		*150	Direct Chlorination
Goodrich, Calvert City, Ky.		1,000	Goodrich Oxychlorination
Monochem, Geismar, La.		350	Acetylene
PPG, Guayanilla, P. R.	900	*500	Oxychlorination
PPG, Lake Charles, La.		*300	Oxychlorination
Shell, Deer Park, Tex.	1,500	*800	Stauffer Oxychlorination
Shell, Norco, La.		*700	Stauffer Oxychlorination
Total		6,695	
Correcting for 90% operating level		670	
Subtotal		6,025	
5% lost in polymerization		300	
Subtotal		5,725	
Estimated 1974 exports		300	
Estimated 1974 imports		Negligible	
Subtotal		5,425	
Other uses of VCM		200	
Total available for PVC conversion		5,225	

*Order of magnitude values

Sources:

(1) Company and industry totals based on Modern Plastics, May, 1974 and plant site estimates based on Chemical Marketing Reporter, 17 September, 1973, and industry interviews.

(2) Industry interviews.

(3) Snell assessment

2. U.S. VCM PRODUCTION HAS INCREASED APPROXIMATELY 370% TO 6,000 MILLION POUNDS IN 1974 SINCE 1964, WHILE THE MID-1974 PRICE IS 7 TO 10 CENTS PER POUND OR ALMOST DOUBLE THE 1972 PRICE

- Exhibit III-2, on the following page, presents production, sales and price data for the years 1962 through 1978-1980 (estimated). Sales and unit cost information are also presented.

- Since 1964 production of VCM has increased from 1,615 million pounds to an estimated 6,025 million pounds in 1974, for an increase of 373%.

- For the years 1962 to 1972, production of VCM increased from 1,311 million pounds to 5,089 million pounds or 388%, while merchant sales increased from 516 million pounds to 3,343 million pounds or 647%. Merchant uses were 39% of production in 1962 and 66% of production in 1972. This indicates a decreased forward integration in the industry with growth.

- The doubling of price from 1972 to mid-1974 is attributed to the great escalation in feedstock costs due to the "energy crisis".

3. THE VCM MANUFACTURING INDUSTRY HAS APPROXIMATELY 940 PRODUCTION WORKERS

- Based on a Snell survey of VCM producers, representing approximately 65% of 1974-1975 nameplate capacity (see Exhibit III-1), estimates were developed of the number of production and related personnel in the industry.

EXHIBIT III-2

USDOL/OSHA

VINYL CHLORIDE MARKET TRENDS

Year	Production[1] (MM Lbs.)	Sales[1] (MM Lbs.)	Unit Value (¢/Lb.)
1962	1,311	516	7.5
1963	1,435	501	7.0
1964	1,615	597	6.4
1965	2,000	688	6.1
1966	2,500	836	5.9
1967	2,424	952	5.3
1968	2,969	1,463	4.6
1969	3,736	2,359	4.4
1970	4,040	2,720	3.9
1971	4,336	3,003	4.2
1972	5,089	3,343	4.0
1973	5,348	NA	5[2]
1974	6,025[3]	NA	7-10[2]
1978--1980 (Unimpacted by OSHA Standards)	6,800[4]	NA	NA

Sources:
(1) "Synthetic Organic Chemicals", U.S. Tariff Commission, Annual Reports 1960-1973.
(2) Posted price in tanks (works, freight equalized), Chemical Marketing Reporter, December 31, 1973 and June 24, 1974.
(3) Estimate based on 1974 capacity 6,695 MM Lbs. in Exhibit III-1 at 90% utilization.
(4) 7,500 MM Lbs. capacity at 90% utilization per Hydrocarbon Processing, May, 1974, p. 83.

NA=Not Available

Exhibit III-3, on the following page, summarizes employment data for 1974

- production, maintenance and laboratory personnel have responsibilities with likelihood of VCM exposure; these represent 720 workers or 77% of manufacturing employment

- there are approximately 220 management and support personnel

* * * * *

This section defined the structure of the VCM industry. The section that follows similarly profiles PVC manufacture.

EXHIBIT III - 3

USDOL/OSHA

VINYL CHLORIDE PRODUCTION WORKERS - 1974

Broad Job Classification	Approximate 1974 Number of Workers	Percent of Total
Production[1]	410	44%
Maintenance[1]	250	27
Laboratory	60	6
Management and Support[2]	220	23
Total VCM Workers Scaled From Snell Survey	940	100%

Notes: (1) Includes line supervisors, such as foremen
(2) Includes plant managers, engineering staff, clerical, etc.

Source: Snell survey of industry covering approximately 65% of 1974-1975 nameplate capacity

IIIB. POLYVINYL CHLORIDE PRODUCTION

This section defines the structure of the polyvinyl chloride (PVC) manufacturing industry. The exhibits supporting this discussion appear sequentially after the text of this section.

1. 21 COMPANIES OPERATE 36 MAJOR PLANTS

- A profile of PVC producers in terms of plant locations, nameplate capacities, and probable polymerizer (reactor) sizes is summarized in Exhibit III-4. Exhibits III-5 and III-6 provide interpretation of these data.

- The total 1974 nameplate capacity of the industry is approximately 5.4 billion pounds per year, with over 1.9 billion pounds of new capacity scheduled over the next two years.

- As shown in Exhibit III-5, no single company dominates PVC production.

  - Goodrich, the largest single producer with five plants, produces approximately 20% of the nation's PVC.

  - The next five largest producers, with a total of nine plants, each produce between 6% and 9% of total production. These producers are Firestone, Conoco, Union Carbide, Borden and Diamond Shamrock.

  - Each of the next thirteen producers, with a total of twenty plants, shares from 1% to less than 5% of total production.

  - The remaining two companies, with a total of two plants, each shares less than 1% of total PVC production.

- PVC is produced in sixteen states, as shown in Exhibit III-6. Production is close to raw material supply (VCM) or near resin market centers.

  - Over 50% of PVC resin capacity is concentrated in five states - Ohio, New Jersey, Texas, Massachusetts and California.

  - Within these five states are located eighteen producing plants.

  - Only ten plants are located in warm climates where open structures are possible; the remaining twenty-six plants are sited in states having moderate to cold temperatures.

- A majority of the operating plants are older than ten years, as estimated in Exhibit III-7.

  - About 58% of the plants are older than ten years.

  - Only 8% of operating plants are less than five years old, with the newest plant starting operation in 1971.

  - Two new plants are scheduled to come on stream in late 1974, and several others are planned for later construction, seen from Exhibit III-4.

- Historically, PVC production has been a batch operation and manufacturing was conducted in relatively small reactors to maintain product flexibility, quality, and most important, these reactors were not available in large capacities.

  - As shown in Exhibit III-4, reactor sizes are almost equally divided between those plants using reactors less than 2,500 gal. capacity, and those between 2,500 gal. and less than 7,500 gal.

  - Only nine plants use polymerizers equal to or larger than 7,500 gal.

According to recent technological developments, the trend is toward larger reactors in new plants. An industry-wide summary of PVC homopolymer production as a function of reactor size in 1972 vs. 1975 is summarized in Exhibit III-8.

- Approximately 85% of the homopolymer produced in 1972 was made in reactors with 7,500 gallons or smaller capacity.

- By 1975, it is expected that the smaller reactors will account for less than 60% of total production.

- Bulk polymerization capacity is expected to almost double.

- The use of small reactors is expected to continue in the long run, but only for production of specialty resins.

The four methods used for polymerizing PVC include suspension, emulsion, bulk, and solution polymerization, with suspension polymerization being used at a majority of plants as shown in Exhibit III-9.

- Suspension resin production is reported in 33 plants, accounting for 78% of 1973 output.

- Emulsion resin production is reported in 16 plants, accounting for 13% of 1973 output.

- Four plants produce bulk resins, while 2 plants produce solution resins, accounting for 9% of 1973 output.

2. THE PVC MANUFACTURING INDUSTRY HAS APPROXIMATELY 5,600 PLANT EMPLOYEES

- Based on the survey of PVC producers by Snell, estimates were developed of the 1974 number of production and related personnel in the industry, as shown in Exhibit III-10.

  - the approximately 3,600 workers identified with suspension processes represent 64% of industry employment, while emulsion process workers represent 27%; bulk and solution process workers represent 9%

  - 65% of PVC plant employment is represented by production workers, while 24% by maintenance personnel; these approximately 3,900 workers have the highest likelihood of VCM exposure.

- The Snell survey yielded an estimate of 5,575 plant employees. A confidential study by industry sources independent of Snell, presented in Exhibit B-1, identified 5,045 workers.

* * * * *

This section defined the structure of the PVC manufacturing sector. The section that follows defines key PVC markets.

EXHIBIT III - 4(1)

USDOL/OSHA

PROFILE OF POLYVINYL CHLORIDE PRODUCERS

Producer	Location	Approximate Nameplate Capacity (million lbs.)	Planned Million Lbs. Per Year	Additions Starting Date	Probable Polymerizer Size Range (gallons) <2,500	2,500 - <7,500	>7,500
Air Products	Calvert City, Ky.	125	200-300	planned		x	
	Pensacola, Fla.	80				x	
American Chemical	Long Beach, Cal.	160			x	x	x
Atlantic Tubing			50	2nd qtr. 1974			
Borden	Illiopolis, Ill.	125	200	late 1974		x	
	Leominster, Mass.	190			x	x	
	Springfield, Mass.	70			x		
Certain-Teed	Lake Charles, La.		300	late 1974		n.a.	
Conoco	Aberdeen, Miss.	250	unspecified	4th qtr.	x	x	x
	Oklahoma City, Okla.	215		1974			x
Diamond Shamrock	Deer Park, Tex.	250	200	late 1974		x	x
	Delaware City, Del.	100				x	x
Ethyl	Baton Rouge, La.	180	unspecified	under way		x	
Firestone	Pottstown, Pa.	190	unspecified	under way	x	x	
	Perryville, Md.	315				x	
General Tire & Rubber	Ashtabula, Ohio	125			x	x	

EXHIBIT III - 4(2)

USDOL/OSHA

PROFILE OF POLYVINYL CHLORIDE PRODUCERS

Producer	Location	Approximate 1974 Nameplate Capacity (million lbs.)	Planned Million Lbs. Per Year	Additions Starting Date	Probable Polymerizer Size Range (gallons)		
					<2,500	2,500 - <7,500	>7,500
Georgia-Pacific	Plaquemine, La.		220	4th qtr. 1974		n.a.	
B. F. Goodrich	Avon Lake, Ohio	315			x	x	
	Henry, Ill.	235			x	x	
	Long Beach, Calif.	190			x	x	
	Louisville, Ky.	180			x	x	
	Pedricktown, N.J.	160			x	x	
Goodyear	Niagara Falls, N. Y.	100			x		x
	Plaquemine, La.	100	100	3rd qtr. 1974	x	x	
Great American Chemical	Fitchburg, Mass.	70			x		
Hooker Chemical	Burlington, N. J.	180		{ expansion held in abeyance			
	Hicksville, N. Y.	15			x		
Keysor-Century	Saugus, Cal.	35			x		
National Starch	Meredosia, Ill.	10 (1)			x		
Olin	Assonet, Mass.	150			x	x	
Pantasote	Passaic, N.J.	60			x		
	Point Pleasant, W. Va.	95 (2)			x	x	

EXHIBIT III - 4(3)

USDOL/OSHA

PROFILE OF POLYVINYL CHLORIDE PRODUCERS

Producer	Location	Approximate 1974 Nameplate Capacity (million lbs.)	Planned Million Lbs. Per Year	Additions Starting Date	Probable Polymerizer Size Range (gallons) <2,500	2,500 - <7,500	>7,500
Robintech	Painesville, Ohio	250	220	4th qtr. 1974		x	
Stauffer	Delaware City, Del.	160	10	3rd qtr. 1975		x	x
			55	3rd qtr. 1976			
Tenneco	Burlington, N.J.	150				x	x
	Flemington, N.J.	85			x	x	
	Pasadena, Tex.		300	4th qtr. 1974		N.A.	
Union Carbide	S. Charleston, W. Va.	160				x	
	Texas City, Tex.	240				x	x
Uniroyal	Painesville, Ohio	120			x	x	—
	Total Nameplate Capacity	5,435	Planned or Anticipated New Capacity	1,900+	22	27	9

Notes: (1) Operates a pilot plant at Plainfield, N.J. with an estimated capacity of 0.2 million pounds
(2) Jointly owned by Pantasote and General Tire & Rubber, and operated by Pantasote

Sources: Chemical Marketing Reporter, May 20, 1974; industry interviews; Modern Plastics, May 1974.

N.A. - not available

EXHIBIT III - 5

USDOL/OSHA

COMPANY CAPACITY AS PERCENT OF TOTAL POLYVINYL CHLORIDE PRODUCTION CAPACITY

Company	1974 Company Nameplate Capacity (million lbs.)	Share of Total Capacity at mid 1974 (percent)	Accumulated Percent
B. F. Goodrich	1080	19.9%	19.9%
Firestone	505	9.3	29.2
Conoco	465	8.6	37.8
Union Carbide	400	7.4	45.2
Borden	385	7.1	52.3
Diamond Shamrock	350	6.4	58.7
Robintech	250	4.6	63.3
Tenneco	235	4.3	67.6
Air Products	205	3.8	71.4
Goodyear	200	3.7	75.1
Hooker	195	3.6	78.7
Ethyl	180	3.3	82.0
Stauffer	160	2.9	84.9
American Chemical	160	2.9	87.8
Pantasote	155	2.9	90.7
Olin	150	2.8	93.5
General Tire	125	2.3	95.8
Uniroyal	120	2.2	98.0
Great American	70	1.3	99.3
Keysor-Century	35	0.6	99.9
National Starch	10	0.2	100.1% (1)
Total	5,435	100.1% (1)	

Note: (1) Does not add to 100% because of rounding errors

Source: Exhibit III - 4 and Snell estimates

EXHIBIT III - 6

USDOL/OSHA

GEOGRAPHIC DISTRIBUTION OF
POLYVINYL CHLORIDE PLANTS - 1971

State	Number of Plants	Production Capacity (million lbs.)	Share of Total Capacity (percent)	Accumulated Percent
Ohio(1)	4	810	14.9 %	14.9 %
New Jersey (1)	5	635	11.7	26.6
Texas (2)	2	490	9.0	35.6
Massachusetts(1)	4	480	8.8	44.4
California (2)	3	385	7.1	51.5
Illinois (1)	3	370	6.8	58.3
Maryland (1)	1	315	5.8	64.1
Kentucky (1)	2	305	5.6	69.7
Louisiana (2)	2	280	5.2	74.9
Delaware (1)	2	260	4.8	79.7
West Virginia (1)	2	255	4.7	84.4
Mississippi (2)	1	250	4.6	89.0
Oklahoma (2)	1	215	4.0	93.0
Pennsylvania (1)	1	190	3.5	96.5
New York (1)	2	115	2.1	98.6
Florida(2)	1	80	1.5	100.1 %(3)
TOTAL	36	5,435	100.1%(3)	
Notes: (1) Sited in moderate to cold climate	26	3,735	68.7	
(2) Sited in warm climate	10	1,700	31.4	
	36	5,435	100.1%(3)	

Source: Exhibit III -4 and Snell estimates

EXHIBIT III - 7(1)

USDOL/OSHA

U. S. POLYVINYL CHLORIDE PLANT AGE - 1974

Producer	Location	Plant Age As Approximately Indicated By Startup Date[1] (years)					
		0 - 5	6 - 10	11 - 15	16 - 20	21 - 25	over 26
Air Products	Calvert City, Ky.			x			
	Pensacola, Fla.				x		
American Chemical	Long Beach, Calif.			x			
Borden	Leominster, Mass.			x			
	Illiopolis, Ill.			x			
	Springfield, Mass.					x	
Conoco	Aberdeen, Miss.		x				
	Oklahoma City, Okla.	x					
Diamond Shamrock	Deer Park, Tex.					x	
	Delaware City, Del.		x				
Ethyl	Baton Rouge, La.		x				
Firestone	Pottstown, Pa.					x	
	Perryville, Md.		x				
General Tire	Ashtabula, Ohio				x		
Goodrich Chemical	Avon Lake, Ohio					x	
	Henry, Ill.		x				
	Long Beach, Calif.			x			
	Louisville, Ky.						x
	Pedricktown, N. J.	x					

EXHIBIT III - 7(2)

USDOL/OSHA

U.S. POLYVINYL CHLORIDE PLANT AGE - 1974

Producer	Location	Plant Age As Approximately Indicated By Startup Date[1] (years)					
		0 - 5	6 - 10	11 - 15	16 - 20	21 - 25	over 26
Goodyear	Niagara Falls, N. Y.						x
	Plaquemine, La.	x					
Great American	Fitchburg, Mass.				x		
Hooker	Hicksville, N. Y.				x		
	Burlington, N. J.		x				
Keysor-Century	Saugus, Calif.				x		
National Starch	Meredosia, Ill.				x		
Olin	Assonet, Mass.		x				
Pantasote	Passaic, N. J.				x		
	Point Pleasant, W. Va.		x[2]				
Robintech	Painesville, Ohio		x				
Stauffer	Delaware City, Del.		x				
Tenneco	Flemington, N. J.				x		
	Burlington, N. J.			x			

EXHIBIT III - 7(3)

USDOL/OSHA

U. S. POLYVINYL CHLORIDE PLANT AGE - 1974

Producer	Location	Plant Age As Approximately Indicated By Startup Date[1] (years)					
		0 - 5	6 - 10	11 - 15	16 - 20	21 - 25	over 26
Union Carbide	S. Charleston, W. Va.		x				
	Texas City, Tex.		x				
Uniroyal	Painesville, Ohio						x
Total		3	12	6	8	4	3

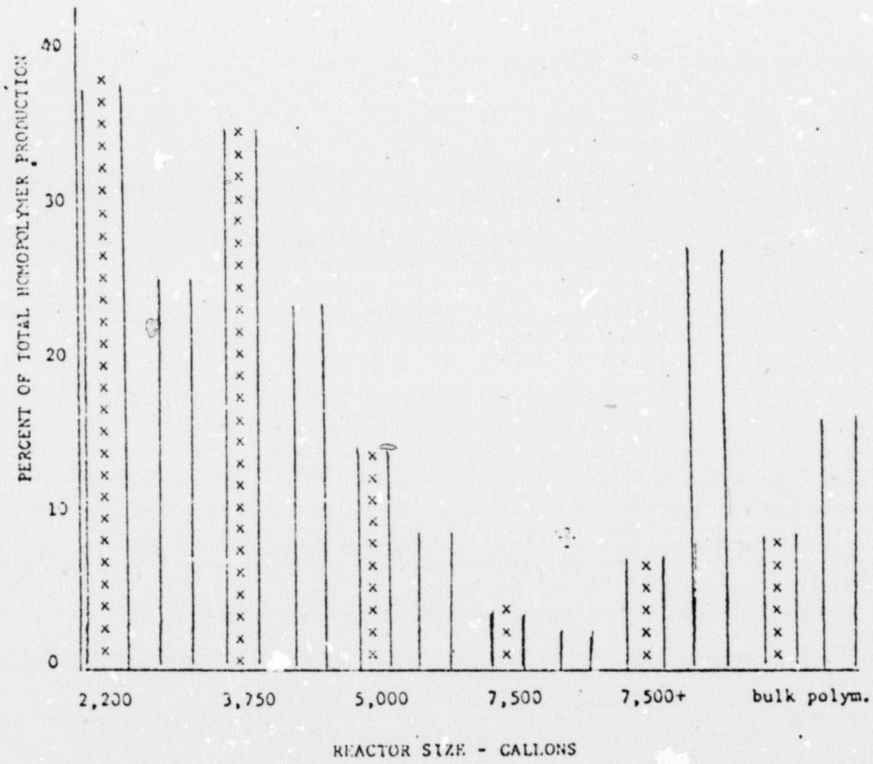
Notes: (1) Or when plant underwent drastic rebuilding
(2) Joint plant with General Tire & Rubber and operated by Pantasote

Source: Snell industry interviews

EXHIBIT III-8

USDOL/OSHA

PVC HOMOPOLYMER PRODUCTION IN VARIOUS SIZE REACTORS - 1972 [X] 1975 [ ]



Note: Assumes no impact from OSHA requirements

Source: Disch, G.E., Plastics -- Raw Materials to End Markets and Coatings-- New Technology and Markets, American Chemical Society, Brooklyn, 1974, p.7.

EXHIBIT III - 9(1)

USDOL/OSHA

POLYVINYL CHLORIDE PRODUCTION BY RESIN TYPE

Producer[1]	Location[1]	Product Line			
		Suspension Resin	Emulsion Resin	Bulk Resin	Solution Resin
Air Products	Calvert City, Ky.	x			
	Pensacola, Fla.	x			
American Chemical	Long Beach, Calif.	x			
Atlantic Tubing		x			
Borden	Leominster, Mass.	x	x		
	Illiopolis, Ill.	x	x		
	Springfield, Mass.	x			
Conoco	Aberdeen, Miss.	x			
	Oklahoma City, Okla.	x			
Diamond Shamrock	Deer Park, Tex.	x	x		
	Delaware City, Del.	x	x		
Ethyl Corp.	Baton Rouge, La.	x	x		
Firestone	Pottstown, Pa.	x	x		
	Perryville, Md.	x			
General Tire	Ashtabula, Ohio	x			

EXHIBIT III - 9(2)

USDOL/OSHA

POLYVINYL CHLORIDE PRODUCTION BY RESIN TYPE

Producer[1]	Location[1]	Product Line: Suspension Resin	Emulsion Resin	Bulk Resin	Solution Resin
Goodrich Chemical	Avon Lake, Ohio	x	x		
	Henry, Ill.	x	x		
	Long Beach, Calif.	x			
	Louisville, Ky.	x	x		
	Pedricktown, N. J.	x	x	x	
Goodyear	Niagara Falls, N. Y.	x	x		
	Plaquemine, La.			x	
Great American	Fitchburg, Mass.	x			
Hooker	Burlington, N.J.			x	
	Hicksville, N. Y.	x			
Keysor-Century	Saugus, Calif.	x			
National Starch	Meredosia, Ill		x		
Olin	Assonet, Mass.	x			
Pantasote	Passaic, N.J.	x			
	Point Pleasant, W. Va.	x			

EXHIBIT III - 9(3)

USDOL/OSHA

POLYVINYL CHLORIDE PRODUCTION BY RESIN TYPE

Producer [1]	Location [1]	Product Line: Suspension Resin	Emulsion Resin	Bulk Resin	Solution Resin
Robintech	Painesville, Ohio	x			
Stauffer	Delaware City, Del.	x	x		
Tenneco	Burlington, N.J.	x	x		
	Flemington, N.J.	x			
Union Carbide	S. Charleston, W. Va.		x		x
	Texas City, Tex.	x		x	x
Uniroyal	Painesville, Ohio	x	x	—	—
Total		33	10	4	2
1973 U. S. Production, million lbs.		3,558	593	274	137
Percent of Total Production		78%	13%	6%	3%

Note: (1) Jointly owned with General Tire, operated by Pantasote

Sources: Industry interviews and Snell assessment of product lines
Monthly Statistical Report, The Society of the Plastics Industry, Inc., April 6, 1973 and March 20, 1974 for production data

EXHIBIT III - 10

USDOL/OSHA

POLYVINYL CHLORIDE PRODUCTION WORKERS - 1974

Broad Job Classification	Workers By Process Type				Total	Percent of Total
	Suspension	Emulsion	Bulk	Solution		
Production (1)	1,920	790	135	185	3,030	55%
Maintenance (1)	790	470	25	(	~ 1,350	24
Laboratory	200	100	{ 25	{ 125	~ 390	7
Management and Support (2)	610	140	{ —	{ —	~ 805	14
Total PVC Industry Workers Scaled From Snell Survey (3)	3,580	1,500	185	310	5,575	100%
Percent of Approximate 1974 Capacity Covered by Snell Survey	79%	67%	100%	100%		

Notes:
(1) Includes line supervisors, such as foremen
(2) Includes plant managers, engineering staff, clerical, etc.
(3) Personnel associated with compounding and fabrication in integrated facilities are not counted

Sources: Snell survey of industry

IIIC. KEY POLYVINYL CHLORIDE MARKETS

This section presents data on polyvinyl chloride (PVC) output trends, prices, end-uses, and polymer characteristics regarding free monomer levels as shipped to fabricators. Supporting exhibits appear sequentially at the end of the text.

1. PVC PRODUCTION HAS INCREASED OVER 300 PERCENT FROM 1963 TO 1973, AND FROM 1972 TO MID-1974 PRICES HAVE APPROXIMATELY DOUBLED

- Exhibit III-11 shows production, sales, and unit value trends since 1960.
  - The increase in output from 1963 to 1973 was 318%.
  - The leveling of output from 1972 to 1973 is attributed to a significant extent to feedstock and capacity shortages.
  - In 1963, captive consumption represented only 13% of production, while in 1972 this was 10%.
  - Unit value has steadily decreased until 1972.
- Exhibit III-12 presents recent price data for the major resin types as well as price and supply/demand forecasts for the 1978-1980 period.
  - Between 1972 and mid-1974 prices have approximately doubled due to the effects of the "energy crisis", for example, from $0.10-$0.11 per lb. in 1972 to $0.21-$0.23 per lb. in mid-1974 for homopolymer resins.
  - By 1978-1980 price leveling is expected, assuming minimal impact from safety and environmental regulations.

- The average expected increase by 1978-1980 in PVC output compared to 1974 levels is of the order of 40%.

- In 1978-1980 VCM supply and PVC capacity is expected to be reasonably balanced if construction expectations materialize, although PVC capacity may be tight.

. Exhibit III-13 summarizes the supply situation of PVC and VCM including imports and exports.

- Exports of PVC remained at approximately 160 million lbs. in 1972 and 1973, while VCM exports dropped 32% from 620 to 420 million lbs.

- Imports of PVC increased over 15 times from 1972 to 1973, from 4 to 65 million lbs., while VCM imports remained essentially negligible.

- Exports represent approximately 4% of U.S. PVC output and 8% of VCM output.

2. MAJOR MARKETS FOR PVC INCLUDE CONSTRUCTION, HOUSEHOLD PRODUCTS, CONSUMER GOODS AND ELECTRICAL USES

. PVC products find use in almost every major sector of the economy as shown in Exhibit III-14.

- Pipe and conduit applications in building and construction are the single most important end-use, accounting for 24% of 1973 consumption.

- Flooring, wire and cable, and furniture account for another 25% of 1973 consumption.

- The more rapidly growing markets for PVC are construction products, packaging, pipe, and fittings.

- More mature segments include apparel, flooring, home furnishing, phonograph records, transportation equipment, and wire and cable coating.

. Exhibit III-15 provides end-use forecasts of the PVC market through 1978-1980.

- During this period consumption is expected to range from 6,330 to 6,820 million lbs.

- Construction is expected to be the dominant segment at approximately 56% market share, a significant increase from approximately 43% in 1973.

3. PVC FABRICATION PROCESSES INCLUDE CALENDERING, COATING, EXTRUSION, MOLDING AND PASTE PROCESSES

. Exhibit III-16 summarizes PVC consumption by major fabrication process as well as resin kind.

. The table below shows the distribution of resin type in 1973 production.

	1973	
Resin Kind & Use	Thousand Lbs.	Percent of Total
Total Polyvinyl Chloride & Copolymers Production (Dry Resin Content)	4,561,500	100
Homopolymer Resins	3,432,677	75
Copolymer Resins	539,627	12
Dispersion Resins, Latexes, & Blending	589,196	13

Source: Exhibit III-16

. The table below shows the distribution of fabrication type in 1973 end-use.

Fabrication Type	1973 Thousand Lbs.	1973 Percent of Total
Calendering	913,166	19.9
Coating	483,583	10.5
Extrusion	2,297,992	50.1
Molding	511,082	11.1
Paste Process	155,577	3.4
All Other	224,391	4.9
Total U.S. Sales and Use	4,585,796	99.9%

Source: Exhibit III-16

. Extrusion is the most important means of fabrication with 50% of the resin processed by this means. Approximately one-half the extrusion throughput is to manufacture rigid pipe and tubing (except fittings).

4. FREE MONOMER LEVELS IN PVC SHIPPED TO FABRICATORS VARY SIGNIFICANTLY AS A FUNCTION OF RESIN TYPE AND MAJOR END-USE

. Exhibit III-17 relates average order of magnitude free monomer levels in the principal types of PVC to major fabrication category.

- The table below summarizes the quantity of resin in three categories of free monomer content.

Possible Free Monomer Level (ppm)	Approximate 1973 U.S. Sales End-Use (Million Lbs.)	Percent of Total
less than 100	805	18%
100 to 500	3,245	70
over 500	540	12
Total	4,590	100%

Source: Exhibit III-17

- According to industry sources with improvements in stripping technology average monomer levels in pipe grade and general purpose resins of less than 100 ppm can be achieved. Thus, the total resin consumption averaging less than 100 ppm average free monomer levels can be 3,850 million pounds on a 1973 annual basis or approximately 84% of the total yearly consumption.

- Stripping of copolymers and latex products to below 100 ppm free monomer levels is reported to require significant technological development.

- Exhibit A-7 in Appendix A broadly discusses stripping technology

* * * * *

This report chapter presented the industry structure of VCM and PVC production and end-uses. The chapter that follows briefly describes the technology of the industry.

EXHIBIT III - 11

USDOL/OSHA

POLYVINYL CHLORIDE AND COPOLYMER RESINS, RESIN EQUIVALENT BASIS

Year	Production 1,000 lbs. dry basis	Sales 1,000 lbs. dry basis	Value 1,000 dollars	Unit Value dollars/lb.
1960	935,508	900,431	208,550	0.232
1961	977,254	965,810	180,741	0.187
1962	1,214,510	1,150,807	202,601	0.176
1963	1,385,845	1,207,102	218,114	0.181
1964	1,636,891	1,373,740	240,056	0.175
1965	1,837,467	1,715,321	297,189	0.173
1966	2,163,561	1,816,457	301,743	0.166
1967	2,142,438	1,927,942	302,110	0.157
1968	2,635,394	2,329,541	326,566	0.140
1969	3,032,063	2,748,068	375,393	0.137
1970	3,115,204	2,847,001	383,506	0.135
1971	3,437,328	2,995,434	402,723	0.134
1972	4,322,000	3,865,000	503,048	0.130
1973 preliminary	4,423,434			

Source: "Synthetic Organic Chemicals", U.S. Tariff Commission, Annual Reports 1960-1973

EXHIBIT III - 12

USDOL/OSHA

POLYVINYL CHLORIDE OUTPUT AND PRICE FORECASTS

Resin	1970[1]	1972[1]	July 1974[2]	1978-19[illegible][1]
Homopolymer Resins, $/lb.	0.10	0.10 - 0.11	0.21 - 0.23	0.22 - 0.[illegible]
Copolymer Resins, $/lb.	0.12	0.13	0.23 - 0.25	0.24 - 0.[illegible]
Dispersion Resins, $/lb.	0.19	0.19	0.31 - 0.35	0.32 - 0.[illegible]
Total PVC Production,[3] Million Lbs.			~ 4,700	6,300 - 6,[illegible]00
PVC Capacity,[3] Million Lbs./Year			~ 5,000	6,120 - 7,[illegible]20
VCM Capacity,[3] Million Lbs./Year			~ 6,200	~ 7,50[illegible]

Note: 1978-1980 values do not include any impact of OSHA regulations, and price and output projections are judged by Snell to be on the low side.

Sources:

(1) Disch, G. E., Plastics--Raw Materials to End Markets and Coatings--New Technology and Markets, American Chemical Society, Brooklyn, 1974, p. 7

(2) Chemical Marketing Reporter, July 22, 1974

(3) Hydrocarbon Processing, May 1974, p. 83

EXHIBIT III - 13(1)

USDOL/OSHA

SUPPLY SITUATION OF POLYVINYL CHLORIDE AND VINYL CHLORIDE
(Million pounds)

Commodity	12 months: Jan. - Dec. 1973	1972	73/72 (percent)	Recent Monthly Trends: Oct. 1973	Nov.	Dec.	Jan. 1974	Feb.	March	April
Production Trends										
PVC	4423	4280	+3	375	368	377	378	372	402	
VCM	5348	5175	+3	472	455	450	495	467	429(2)	
Export Trends										
PVC	162	158	+3	16	18	15	15	27	33	31
VCM	420	620	-32	28	30	41	36	24	45	52
Import Trends										
PVC	65	4	+1525	6	4	6	4	6	3	
VCM	2	neg.	-	neg.	-	1	0.3	-	neg.	
Net Supply (1,2)										
PVC	4326	4135	+5	365	354	368	357	351	372	
VCM	4930	4555	+8	444	425	410	459	443	384	

EXHIBIT III - 13(2)

USDOL/OSHA

SUPPLY SITUATION OF POLYVINYL CHLORIDE AND VINYL CHLORIDE
(Million pounds)

	Exports As Percent of Production			
	1973	1972	Oct. - Jan. 1973 (cum.)	Jan. - Feb. 1974 (cum.)
PVC	3.7	3.6	4.4	3.6
VCM	7.9	12.0	7.2	6.2

Notes: (1) Long-term contracts about 65%
(2) Net supply equals production plus imports less exports

Source: Chemicals and Rubber Program, Office of Business Research and Analysis, U. S. Department of Commerce, April 16, 1974

EXHIBIT III - 14(1)

USDOL/OSHA

POLYVINYL CHLORIDE MAJOR MARKETS
1970 - 1973 (million pounds)

Market	1970	1971	1972	1973
Apparel				
Baby Pants	23.0	19.8	24.2	26.4
Footwear	110.0	112.2	140.8	145.2
Outerwear	47.0	50.6	66.0	68.2
Building and Construction				
Extruded foam moldings	na	6.6	50.6	57.2
Flooring	325.0	288.2	470.8	464.2
Lighting	9.0	8.8	11.0	11.0
Panels and siding	60.0	59.4	70.4	85.8
Pipe and conduit	475.0	583.0	803.0	1155.0
Pipe fittings		74.8	85.8	90.8
Rainwater systems, soffits, fascias	na	28.6	30.8	35.2
Swimming pool liners	35.0	39.6	44.0	39.6
Weatherstripping	30.0	30.8	39.6	35.2
Windows, other profiles	45.0	50.6	55.0	57.2
Electrical				
Wire and cable	410.0	354.2	429.0	426.8
Home furnishings				
Appliances	21.0	28.6	35.2	44.0
Furniture	247.0	250.8	297.0	319.0
Garden hose	35.0	33.0	44.0	39.6
Housewares	80.0	81.4	103.4	112.2
Wall coverings and wood surfacing films	97.0	101.2	127.6	118.8

EXHIBIT III - 14(2)

USDOL/OSHA

POLYVINYL CHLORIDE MAJOR MARKETS
1970 - 1973 (million pounds)

Markets	1970	1971	1972	1973
Packaging				
Blow molded bottles	70.0	50.6	70.4	79.2
Closure liners and gaskets	12.0	15.4	17.6	19.8
Coatings	15.0	15.4	17.6	19.8
Film	115.0	110.0	136.4	129.8
Sheet	60.0	75.9	88.0	77.0
Recreation				
Records	140.0	132.0	149.6	145.2
Sporting goods	35.0	39.6	50.6	55.0
Toys	60.0	59.4	74.8	83.6
Transportation				
Auto mats	35.0	37.4	39.6	39.6
Auto tops	30.0	33.0	35.2	33.0
Upholstery and seat covers	150.0	169.4	180.4	182.6
Miscellaneous				
Agriculture	24.0	24.2	116.6	145.2
Credit cards	11.0	11.0	15.4	17.6
Laminates	38.0	37.4	48.4	50.6
Medical tubing	32.0	35.2	46.2	50.6

EXHIBIT III - 14(3)

USDOL/OSHA

POLYVINYL CHLORIDE MAJOR MARKETS
1970 - 1973 (million pounds)

Market	1970	1971	1972	1973
Novelties	10.0	8.8	13.2	15.4
Stationery supplies	27.0	26.4	35.2	39.6
Tools and hardware	10.0	11.0	13.2	17.6
Export (Net)	190.0	165.0	160.6	138.6
Other	94.0	190.9	107.8	99.0
Total	3027.0	3456.2	4345.0	4776.2

Sources: Modern Plastics, January 1971, 1972, 1973, 1974

EXHIBIT III - 15

USDOL/OSHA

END USE FORECASTS OF POLYVINYL CHLORIDE MARKET, 1974 and 1978 - 1980

Polyvinyl Chloride End Use Market
(million lbs.)

End Uses	1974	1978-1980
Construction	2,250	3,500 - 3,800
Household Uses	640	680 - 735
Packaging	320	440 - 475
Electrical Uses	410	520 - 540
Consumer Goods	520	570 - 625
Transportation	260	280 - 295
Miscellaneous	200	240 - 250
Exports	150	100
	4,750	6,330 - 6,820

Source: Disch, G. E., Plastics--Raw Materials to End Markets and Coatings--New Technology and Markets, American Chemical Society, Brooklyn, 1974, p. 3.

EXHIBIT III - 16(1)

USDOL/OSHA

POLYVINYL CHLORIDE CONSUMPTION BY MAJOR FABRICATION PROCESS - 1970 TO 197[illegible] (000 LBS. DRY WEIGHT)

(P) = Production
(S) = Sales
(U) = Internal Use

Resin Kind & Use	1970	1971	1972	1973
Total Polyvinyl Chloride & Copolymers (P)				
(Dry Resin Content)	3,115,204	3,437,328	4,258,719	4,561,509
Homopolymer Resins	2,232,008	2,474,900	3,149,421	3,432,677
Copolymer Resins	519,026	504,461	559,338	539,827
Dispersion Resins, Latexes, & Blending	364,170	457,961	549,960	589,190
Total Polyvinyl Chloride & Copolymers (S & U)				
(Dry Resin Content)	2,985,214	3,394,185	4,336,880	4,732,157
Total Exports	187,994	169,454	155,910	146,361
Total Domestic	2,797,220	3,224,731	4,180,970	4,585,796
Calendering, Total	705,184	835,114	903,404	913,166
Flooring	247,227	274,544	332,681	292,250
Textile	-	86,934	74,519	72,937
All Other Calendering Uses	457,957	473,636	556,204	548,079
Coating, Total	253,808	349,189	425,273	483,583
Flooring	75,074	116,629	133,645	150,329
Textile & Paper Coating	93,395	142,465	173,237	190,931
Protective Coatings	-	41,060	59,358	71,009
Adhesives & All Other Coating Uses	85,399	49,035	59,033	71,328

EXHIBIT III - 16(2)

USDOL/OSHA

POLYVINYL CHLORIDE CONSUMPTION BY MAJOR FABRICATION PROCESS - 1970 TO 197[illegible] (000 LBS. DRY WEIGHT)

Resin Kind & Use	1970	1971	1972	1973
Extrusion, Total	1,094,775	1,294,684	2,051,008	2,297,99[illegible]
Wire & Cable	408,720	342,919	439,055	413,78[illegible]
Film & Sheet	193,620	178,935	220,145	204,20[illegible]
Rigid Pipe & Tubing (Except Fittings)	-	497,062	1,008,077	1,254,91[illegible]
All Other Extrusions	492,429	275,768	384,331	425,02[illegible]
Molding, Total	253,945	309,070	410,275	511,06[illegible]
Bottles	-	30,119	77,254	87,03[illegible]
Sound Records	140,580	137,846	143,028	144,11[illegible]
Fittings (Rigid Pipe & Tubing)	-	-	(1)	88,00[illegible] (2)
All Other Molding	113,365	135,105	184,993	191,92[illegible]
Paste Processes (Except Coating)	113,054	105,945	150,099	155,577
Plastisol Formulation	113,054	105,945	91,337	86,14[illegible]
All Other	-	-	58,762	69,42[illegible]
All Other Uses	376,394	330,729	180,311	224,39[illegible]

Notes: (1) Comparable 1972 data not available
(2) Not comparable because fittings were included in all other moldings in 1972

Sources: "Synthetic Organic Chemicals", U.S. Tariff Commission, Annual Reports 1971 and 1972.
Monthly Statistical Report, The Society of the Plastics Industry, Inc., April 6, 1973 and March 20, 1974.

EXHIBIT III - 17

USDOL/OSHA

MAJOR RESIN TYPES AND THEIR TYPICAL FREE MONOMER LEVELS RELATED TO FABRICATION CATEGORY

(Million Pounds)

Resin Type	Typical Average Mid-1974 Residual VCM Levels[1] (ppm)	Calendering	Coating	Extrusion	Molding	Paste	All Other	1973 Total
Suspension								
Pipe Grade	150			1,255				1,255
General Purpose	less than 500	550	215	840	185			1,700
Copolymer	1,000 - 7,000	290			90		160	540
Overall	500							
Dispersion								
Latex	400		200					200
Other	less than 25				240	155		395
Overall	10							
Bulk								
High Porosity	25	70		205				275
Overall	25							
Solution								
Overall	1.5		70				65	135
		910	485	2,300	515	155	225	4,500

Note: (1) Individual data points around the averages can vary by a factor of three or more. Before steps were taken to comply with the Emergency Temporary Standard these averages were significantly higher. Improved stripping is believed to have been achieved using state-of-the-art technology and operating procedures. Some major producers reported average VCM levels in general purpose resin significantly below 500 ppm and as low as 50 ppm.

Sources: Snell estimates and Exhibit III-14 and III-16 based on industry interviews.

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IV. TECHNOLOGY OVERVIEW

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IV. TECHNOLOGY OVERVIEW

The previous chapter defined the economic infrastructure of the vinyl chloride (VCM) and polyvinyl chloride (PVC) industries. This chapter presents a technological overview of VCM and PVC manufacture to provide broad engineering and operational perspective to the information of Section V, which presents findings and conclusions.

This chapter is divided into two sections:

- Section IVA, Vinyl Chloride
- Section IVB, Polyvinyl Chloride

PVC is given significantly greater discussion emphasis than VCM since the study is primarily of PVC.

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IVA. VINYL CHLORIDE

This section discusses the technology of vinyl chloride (VCM) manufacture. Exhibits appear sequentially at the end of the text.

1. THE OXYCHLORINATION PROCESS ACCOUNTS FOR APPROXIMATELY 80% OF VCM CAPACITY

The table below summarizes estimated U.S. VCM capacity in 1974 as a function of the manufacturing process.

VCM Process	Estimated 1974 Nameplate Capacity (Million Lbs.)	Percent of Total
Oxychlorination	5,450	81%
Direct Chlorination Only	900	14
Acetylene	350	5
Total	6,700	100%

Source: Exhibit III - 1

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The balanced oxychlorination process is described by the following equations:

Direct Chlorination: (1) $CH_2 = CH_2 + Cl_2 \longrightarrow ClCH_2CH_2Cl$

Oxychlorination (2) $CH_2 = CH_2 + 2HCl + \frac{1}{2}O_2 \xrightarrow[250^{\circ} C]{CuCl_2} ClCH_2CH_2Cl + H_2O$

EDC Cracking (3) $2ClCH_2CH_2Cl \xrightarrow[400^{\circ} C]{} 2CH_2 = CHCl + 2HCl$

Net $2\,CH_2 = CH_2 + Cl_2 + \frac{1}{2}O_2 \longrightarrow 2CH_2 = CHCl + H_2O$

Source: Brownstein, A.M., U. S. Petrochemicals. Tulsa, Oklahoma; The Petroleum Publishing Co., 1971, p. 250.

Exhibits IV-1 and IV-2 provide representative flow diagrams for the balanced oxychlorination process based on the Stauffer Chemical and B. F. Goodrich Chemical designs, respectively. Unit operations are similar in balanced oxychlorination plants, although design details can vary appreciably regarding mass and heat balances, particularly in fractionation steps.

Exhibit IV-3 provides a general process description related to the Stauffer design. The Exhibit also provides a more detailed description of unit operations involving VCM.

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- The American Chemical plant is believed to feature unbalanced oxychlorination, using only reactions (2) and (3) in the preceding table.

- The Ethyl plants and Dow's Plaquemine plant are believed to feature direct chlorination and cracking only, using reactions (1) and (3) in the preceding table.

- The Monomchem plant, the only substantial acetylene-based process still operating, is believed to be balanced type employing both ethylene and acetylene. The HCl produced by pyrolysis of ethylene dichloride is added to acetylene for further VCM production, instead of oxychlorination.

- The newest process is the Transcat process (Lummus Co., and Armstrong Cork Co.) with the potential to compete strongly with the ethylene process. It is one step synthesis of VCM by oxychlorination of ethane. VCM is produced by passing ethane, HCl and air (1 to 1 to 2.5 vol) through a molten catalyst of KCl and $CuCl/CuCl_2$ at 875°F.

2. VCM PRODUCTION COSTS WERE ESTIMATED FOR 1974 TO PROVIDE THE BASIS FOR THE ECONOMIC IMPACT ASSESSMENT

- Exhibit IV-4 summarizes estimated 1974 VCM economics.

- The data is provided in terms of unit costs of manufacture and profitability to enable sensitivity analysis of the potential impacts upon price of various VCM exposure limitation scenarios.

3. GENERALLY, VCM PRODUCTION CAN PRESENT RELATIVELY LIMITED CHANGES OF EXPOSURE TO THE OPERATING PERSONNEL DUE TO AUTOMATION AND REMOTE CONTROL AND OUTDOOR CONSTRUCTION SIMILAR TO REFINERIES

However, localized hazard areas are associated on a routine basis with the loading of tank cars, the cleaning of tank cars and of other equipment. Maintenance operations may be also a source of personnel exposure.

(1) The VCM Production Plants Are Highly Automated, Continuous And Closed Systems

- A typical VCM production plant consists of an island of process units, principally fractionation and similar towers, cracking furnaces, and sometimes compressors. Day tanks, providing storage space during testing, are also included.

- Long-term storage is provided by Hortonspheres which are located in tank farms and connected to the loading racks where the tank cars are filled.

- The flow of material through the production train (or trains) is controlled from control rooms, which, especially in newer installations, are fairly removed from the actual production units

- The operators spend much of their time in the control room, mostly monitoring the operation of automatic controllers and from time to time making necessary set point adjustments. Normally there is little need for the operating personnel to be physically present in the production area.

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- However, inspection trips may be necessary from time to time and are usually motivated by some abnormality in the operation. While most of the abnormalities are usually traceable to instruments or control malfunction, significant leaks could be occurring and result in appreciable exposure risk.

(2) The VCM Plants Are Usually Completely Outdoor Operations

- All production equipment is generally installed out-of-doors. There is limited chance of VCM accumulation and area concentrations may remain low even in the presence of significant leaks, particularly when atmospheric conditions are not stagnant.

- However, significant exposure may be encountered by the greaser. Since his function is to fill up the lubricating devices of pumps and compressors, which in some instances may have to be done daily, he comes into close proximity of seals which may be leaking, and his own personal exposure may be in considerable excess to what would be surmised from the general background.

(3) Tank Car Loading And Tank Car Cleaning Present Critical Areas Of Routine Exposure In Monomer Plants

- While there are some "over-the-fence" pipeline deliveries and some marine shipments, the bulk of the VCM is moved in railroad tank cars. Significant VCM exposure risk can result from disconnecting transfer lines and from the historical practice to use "dip tubes" to determine the level in the tank car.

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- The "dip tube" method consists in allowing a minute amount of VCM gas continuously to escape through an adjustable tube dipping into the tank. When the level of the liquid in the car reaches the bottom of the tube liquid VCM is discharged resulting in a visible "plume" from the tube. Usual practice has been to raise further the dip tube at this point and to complete the filling carefully at a lower rate until the permissible level was reached. Under certain atmospheric conditions this method is known to have given significant VCM concentrations even at some distance from the tank car dome. A solution to this problem has been to re-equip larger fleets of tank cars with more elaborate, non-emitting gauging devices.

- Tank car cleaning operations put men in close contact with cars which may contain residual amounts of monomer. But thorough venting and incineration can be installed and personal protection used. Thus, exposure hazard to personnel can be minimized.

(4) Maintenance Operations, While Serious Potential Sources Of Personnel Exposure, Can Be Controlled By Appropriate Depressurization And Venting Procedures

- Catastrophic failures involving rupture of large volume containers or massive leaks upstream of the main control device are rare.

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- Other situations requiring maintenance action (such as pulling a unit off the line for repair) divide into two categories: scheduled and unscheduled, with the former more easily accomplished using proper procedures to minimize VCM exposure risks.

- Appropriate operating procedures and additional venting equipment can be used to reduce or to virtually eliminate the risk of exposure. Exhibit IV-5 shows an example of current operating procedure for maintenance action of the Dow Chemical Company

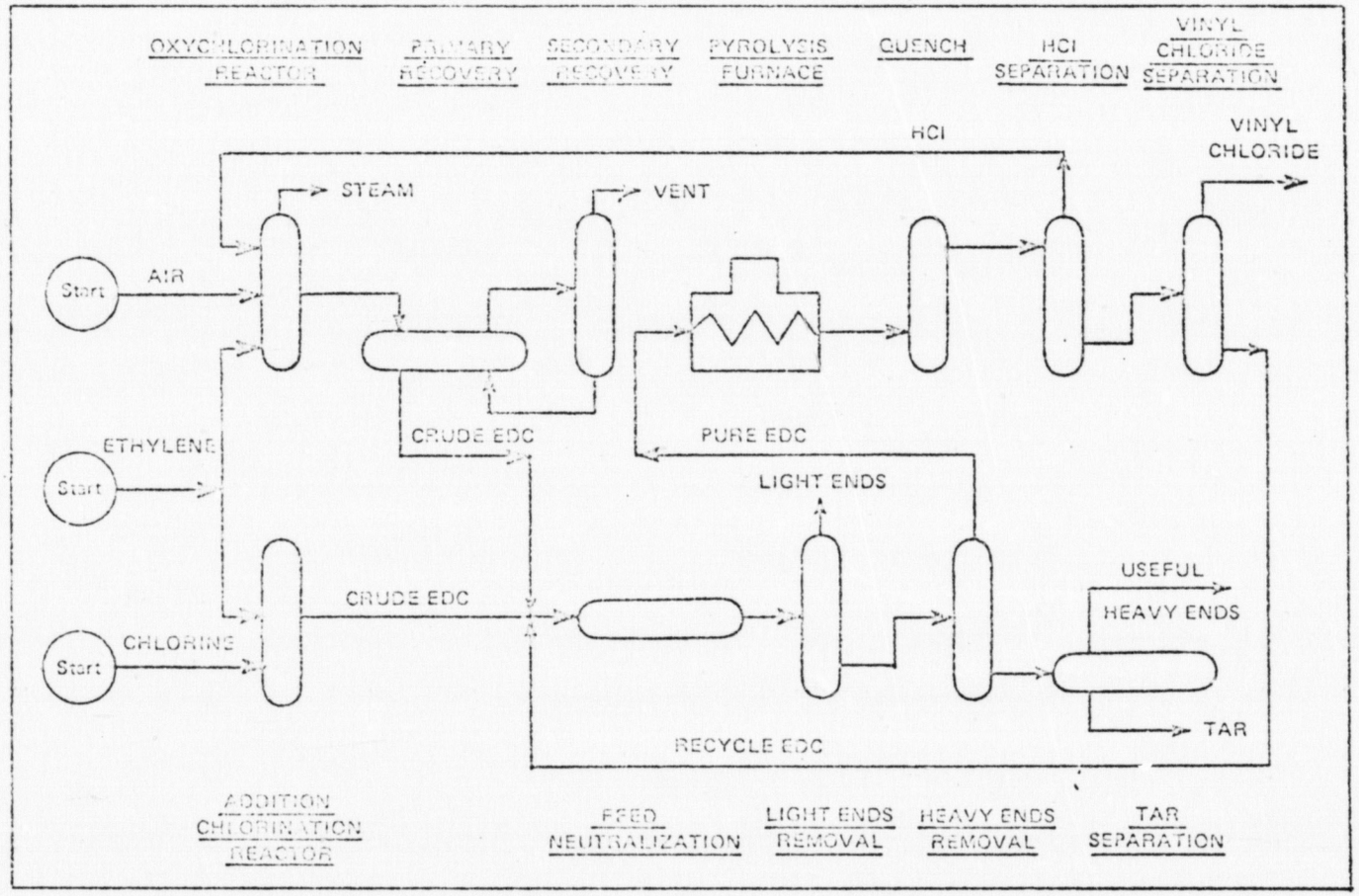
* * * * *

Section IVB, following, provides a similar overview of polyvinyl chloride technology.

EXHIBIT IV–1

USDOL/ OSHA

THE STAUFFER PROCESS FOR VINYL CHLORIDE



Source: Stauffer Chemical Co.: Vinyl Chloride. Hydrocarbon Processing 52: 194, November 1973.

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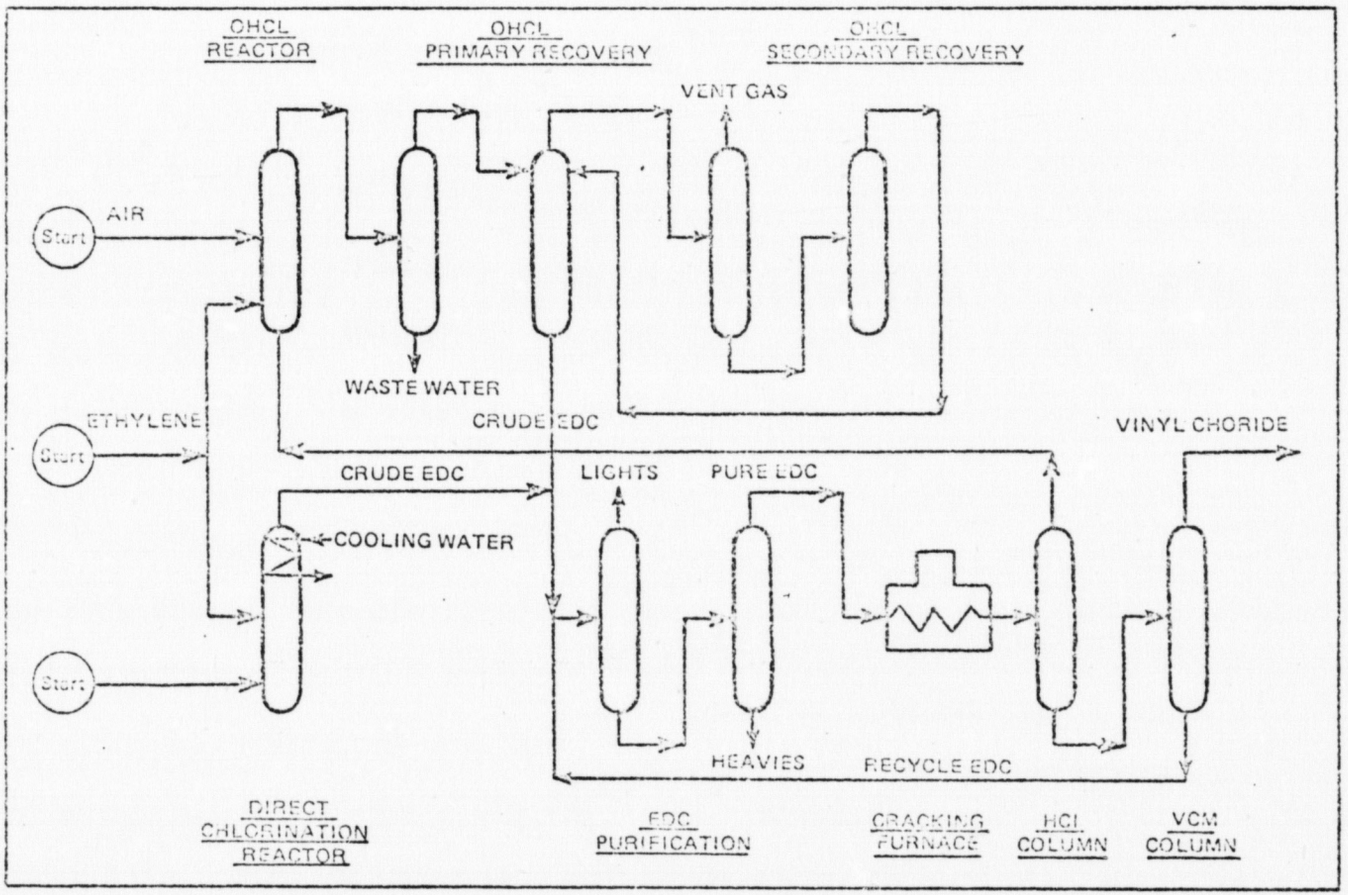
EXHIBIT IV–2

USDOL/OSHA

THE B. F. GOODRICH PROCESS FOR VINYL CHLORIDE



Source: B. F. Goodrich Chemical Co.: Vinyl Chloride. Hydrocarbon Processing 52: 191, November 1973.

VINYL CHLORIDE PROCESS DESCRIPTION

General Description[1]

Ethylene dichloride (EDC) is produced in both addition (direct) chlorination and oxychlorination units. In the addition chlorination unit ethylene and chlorine are combined to produce EDC in a liquid phase reactor. In the oxychlorination unit ethylene, air and byproduct HCl from the EDC cracking unit are reacted to produce EDC. An efficient catalyst in the vapor phase oxychlorination reactor is used to promote high yields. High pressure steam generated in the oxy reactor removes reaction heat and is used as heat medium in other points in the process. EDC is separated from vent gas by condensation in two recovery units. There are no moving parts in the entire oxy process except in the air compressor and refrigeration units.

Crude EDC from the addition and the oxychlori tion units is combined with recycle EDC from the cracking unit and purified by removal of small quantities of light and heavy materials. Aqueous effluents seperated from the crude EDC are steam stripped and are suitable for biological treatment. Both light and heavy ends may be treated for further use as feed to other chlorination processes.

Vinyl chloride monomer (VCM) is produced by cracking purified EDC in the pyrolysis furnace.

Description of Unit Operations Involving VCM[2]

Dry EDC is dehydrochlorinated to vinyl chloride as it passes through the packed tubes of a cracking furnace.

The tubes are normally packed with pumice, charcoal or some other "contact" type catalyst. At 900 to 950° F and 50 PSIG, EDC conversion is about 50% and yield to vinyl chloride is 94 to 97 mole%. The hot effluent gases are then quenched, and partially condensed, by direct contact with cold EDC in a quench tower.

Effluent fractionation and product purification are generally accomplished in three additional towers, where each producer of VCM has its own modification of this process.

Hydrogen chloride and light chlorinated hydrocarbons are rejected overhead in the "HCL" and "Light Ends" towers. The hydrogen chloride is normally recovered by water scrubbing and recycled to the EDC plant. Trichloroethane, chlorinated C_4's and other heavy ends are rejected from the bottom of either the "quench tower" or the "vinyl tower". Contained EDC is recovered by fractionation and recycled to both the quench tower and the feed storage tank. The light and heavy ends are either further processed or disposed of by, for example, incineration. Vinyl chloride monomer is taken overhead in the "vinyl" column, generally caustic washed, and then sent to the product storage facilities.

EXHIBIT IV-3 (2)

USDOL/OSHA

VINYL CHLORIDE PROCESS DESCRIPTION

General Description[1]

After quenching, the furnace products are seperated into HCl, which is recycled to the oxy unit, and high purity VCM. Unreacted EDC is recycled through the EDC purification system.

The overall process is balanced so that only VCM is produced without byproduct HCl. Design is easily adapted to produce HCl for other uses, to use HCl from other sources, or to make EDC as a seperate product.

The process is highly automated for stable, fail-safe operation at high yields over a wide turn-down range. Startup is easy and rapid. Units combine simplicity of operation with low manpower, capital, operating and maintenance costs.

Notes:
(1) Related to the Stauffer process, Exhibit IV-1
(2) Reflects generalized practice

Sources:
(1) Stauffer Chemical Co.: Vinyl Chloride. Hydrocarbon Processing 52: 194, November 1973.
(2) Air Products & Chemicals, Inc. Houdry Division, Survey Report on Vinyl Chloride Monomer Production Via Dichlorethane Pyrolysis. Prepared for Environmental Protection Agency; Durham, North Carolina; 1972.

EXHIBIT IV - 4 (1)

USDOL/OSHA

ESTIMATED VINYL CHLORIDE MONOMER
ECONOMICS - 1974
(¢/lb.)

Unit Production Costs For A 500 Million Lb. Ethylene Oxychlorination Plant of 1974 Construction With Total Fixed Capital of $20.4 Million

Plant investment	4.08	
Cost of Manufacture		
Raw Materials		
Ethylene (0.49 lb/lb @ 6.0¢/lb)	2.94	
Chlorine (0.67 lb/lb @ 3.0¢/lb)	2.01	
Subtotal		4.95
Labor	0.12	
Utilities	0.25	
Maintenance	0.20	
Overhead	0.15	
Taxes & Insurance	0.06	
Depreciation	0.40	
Total cost of manufacture		6.13

EXHIBIT IV - 4(2)

USDOL/OSHA

ESTIMATED VINYL CHLORIDE MONOMER ECONOMICS - 1974 (¢/lb.)

Unit Production Costs For A 500 Million Lb. Ethylene Oxychlorination Plant of 1974 Construction With Total Fixed Capital of $20.4 Million

Profitability

Net selling price (FOB plant)	7.41
Cost of manufacture	(6.13)
Selling, general and administrative expenses	~ (0.30)
Pretax profit	0.98
Pretax return on total investment (@ 1.2 plant investment)	20%

Sources:

(1) Snell estimates based on Brownstein, A. M., U. S. Petrochemicals, Tulsa, Oklahoma, The Petroleum Publishing Co., 1971, p. 25

(2) Snell estimates based on mid-1974 Chemical Marketing Reporter posted prices

EXHIBIT IV-5 (1)

USDOL/OSHA

EXAMPLE OF A STANDARD OPERATING PROCEDURE FOR
MAINTENANCE AT DOW CHEMICAL CO. VINYL CHLORIDE WORKS

SAFETY PROCEDURE

Subject: BLEED-DOWN OF VINYL CHLORIDE CONTAINING EQUIPMENT

Problem: At present, pumps, sections of piping, and some equipment are partially or otherwise bled down to atmosphere. This exposes personnel to vinyl vapors if care is not taken.

Situation: Obviously, there are numerous situations that occur in the plant, where exposure to vinyl vapors is possible when preparing equipment for repair or entry. Most equipment is either already tied into the vent recovery system for bleed-down, or can be, with limited temporary piping. Almost all bleed-downs can be done through the vent recovery system and all personnel exposures to vinyl vapors must be eliminated. Elimination of exposure to the vapors should extend to any final low pressure bleed-down of equipment that has already been relieved through the vent recovery system. Also, preventative measures should be taken when opening equipment with stagnated vapors in it. In these two cases, proper respirators should be used to prevent exposures due to change of wind direction or otherwise.

Solution:

1. All seal repair work done on vinyl furnace pumps should utilize the vent recovery system for the primary bleed-down. Any small final bleed-down should involve personal respirator protection. In some cases, it may be necessary to use a full face mask, rather than a mouth-bite respirator.

2. Temporary piping to the vent recovery system should be run when necessary to vent an isolated piece of equipment, or run of piping.

3. When breaking into a vessel or piping system containing vinyl that has been depressured, use a respirator. (Hose-Line Mask). In the case of breaking vinyl containing system, the use of respirators should parallel the policy of using monogoggles.

4. All vessels will be purged to D-234 vent recovery system before opening. Considerable exposure to vinyl vapors is possible working around these openings due to trapped liquid vaporization inside the vessel. Therefore, fresh air-supplied masks should be used around such openings for exposures of any length.

5. When breaking into vinyl containing equipment, the immediate supervisor of that area should advise the type of respiratory equipment to be used, and issue a safe work permit in some cases.

Source: Dow Chemical Corporation

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IVB. POLYVINYL CHLORIDE

This chapter discusses the technology of polyvinyl chloride (PVC) manufacture in broad terms. Appendix A provides more detailed data from contacts with industry, from submissions to OSHA related to the "Proposed Standard" and other sources. All exhibits appear sequentially at the end of the chapter.

There are four basic processes which can be used for producing PVC.

- Suspension Polymerization
- Emulsion Polymerization
- Bulk Polymerization
- Solution Polymerization

These processes are presented in a "capsule" summary in Exhibit IV-6.

1. OF THE FOUR PROCESSES FOR THE MANUFACTURE OF PVC THE SUSPENSION PROCESS IS THE MOST ECONOMICALLY IMPORTANT, ACCOUNTING FOR 78 PERCENT OF PRODUCTION

- The table on the following page summarizes the relative contribution of each process to the total production for 1973.

Process	1973 Production (Million Lbs.)	Percent of Production
Suspension	3,558	78
Emulsion	593	13
Bulk	274	6
Solution	137	3
Total	4,562	100%

Source: Exhibit III-9

The importance of the suspension process is reflected in subsequent discussion.

Exhibit IV-7 presents a flow diagram for a representative suspension process. Principal unit operations include

- monomer receiving and storage. This is discussed in Appendix A, where Exhibit A-1 presents operating procedures while Exhibit A-2 shows a flow sheet.
- polymerization
  - this is also discussed in Appendix A, where a technological assessment was developed by Snell addressing reactor design and cleaning in Exhibit A-3.
  - a comparison is also presented of large versus small reactor technology in Exhibit A-4.
  - Exhibit A-5 shows the schematic of an older polymerizer, while Exhibit A-6 shows that of a newer design.
- stripping and in-process storage. Stripping technology is broadly discussed in Exhibit A-7.
- drying
- finished product handling

- Exhibit A-8 in Appendix A provides a representative plant layout with typical operator movements.

- Exhibit A-9 in Appendix A presents a flow diagram of emulsion polymerization.

- It is seen from Exhibit IV-8, at the end of this chapter, providing a technological overview of suspension polymerization, emulsion polymerization and their copolymer production variants that suspension and emulsion polymerization are very similar in terms of gross equipment used. Differences in detail are summarized in the Exhibit.

- Exhibit IV [illegible]nts an overview of the polymerization cycle for the suspension and emuls[illegible]sses. Differences principally concern time requirements, detailed in [illegible] Exhibit.

- Exhibit IV-10 provides a checklist of potential VCM sources contributing to local or area type VCM exposure risk in suspension polymerization. The most important potential sources are identified in the Exhibit.

- Exhibit IV-11 shows a flow diagram and process description for bulk polymerization.

- Exhibit IV-12 presents a summary discussion of copolymers manufacture, which involves the suspension, emulsion or solution processes.

2. ESTIMATES WERE DEVELOPED BY SNELL OF PVC INDUSTRY ECONOMICS AND THE TIME REQUIRED TO ACHIEVE VARIOUS ENGINEERING GOALS

- Exhibit IV-13 presents typical time requirements for implementing various engineering control methods.

- Typical delivery times were also estimated for key equipment items and these are presented in Appendix C, Exhibit C-1.

- Exhibit C-2 presents Snell's overview of time requirements in implementing engineered controls of VCM exposure in PVC plants.

- Exhibit IV-14, at the end of this chapter, summarizes 1974 PVC economics. Total cost of manufacture is estimated at 14.4¢/lb. at a 20% pretax return on total investment. This cost profile is used in the next chapter in economic impact evaluations of various VCM compliance scenarios.

* * * * *

This chapter discussed the technology and basic production economics of VCM and PVC manufacture. The next chapter presents findings and conclusions.

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Exhibit IV-6

USDOL/OSHA

CAPSULE OVERVIEW OF POLYVINYL CHLORIDE PROCESSES

Suspension Polymerization[1,3]

Suspension polymerization uses water as a medium for VCM with a suspension agent such as polyvinyl alcohol and a catalyst such as benzoyl peroxide. Buffers such as sodium carbonates or phosphate can be used to maintain pH at 5 to 8 during the reaction and prevent hydrochloric acid evolution. Polymerization under nitrogen increases reaction rate as well as controls acid release.

The charge to a reactor might be composed of:

- 100 part VCM
- 200 parts water
- 0.1-0.2 part catalyst
- 0.035-0.1 part suspension agent

The VCM/water ratio is limited by the rheology of the suspension to enable proper removal of the heat of polymerization. Vigorous agitation aids heat exchange and maintains VCM as fine droplets suspended in water. After drying the polymer "pearls" range from 90 to 150 microns for general purpose applications, and smaller for specialty products.

Process temperatures range from 30 to 45°C, and the time to turn around a polymerizer can range from 5 to 15 hours.

Major uses of suspension polymerized PVC are in calendered film; extruded film, wire coatings, pipe and profile; and molded products.

Emulsion Polymerization[1,2,3]

Emulsion (dispersion or paste) polymerization is very similar to the suspension process. Recipe differences principally concern the use of emulsifiers and initiators. The time to turn around a reactor can range from 10 to 25 hours.

A colloid dispersion of PVC particles in an aqueous phase is produced in this process. These particles, approximately 0.5 microns in size, can be utilized directly from the dispersion, or latex, either plasticized or unplasticized, or they can be spray dried to a powder for use in plastisols, rigidsols, plastigels, or organosols. Processes utilizing PVC dispersion resins include slush molding, casting, dipping, spray coating, roll and knife coating, and rotational molding.

Plastisols are vinyl dispersions containing little or no volatile liquids and thus are essentially 100% solids. Organosols are similar in composition to plastisols except for the presence of volatile liquids used to extend the liquid phase and thus reduce viscosity.

Polyvinyl chloride for plastisols and organosols is polymerized in emulsion systems that provide colloidal water dispersions containing ultimate particles of approximately 0.2 to 2.0 microns in size. Spray drying of the water dispersion produces the commercial product, a dry powder of approximately 2 microns average particle size, with some particles as large as 15 to 20 microns. About 10% of the PVC used in the U.S. is dispersion grade.

Most vinyl dispersion resins find use in the two broad areas of coating and moldings.

Organosols are used to produce thin films of higher hardness than can generally be obtained from plastisols.

Latex liquid systems of vinyl chloride homopolymers and copolymers are also available. These systems are colloidal dispersions in water. The average particle size is usually less than 0.3 micron.

Latexes are effectively used to coat, impregnate or saturate fabrics, paper and leather with polymeric dispersions of lower viscosity than most plastisols.

Bulk Polymerization[1]

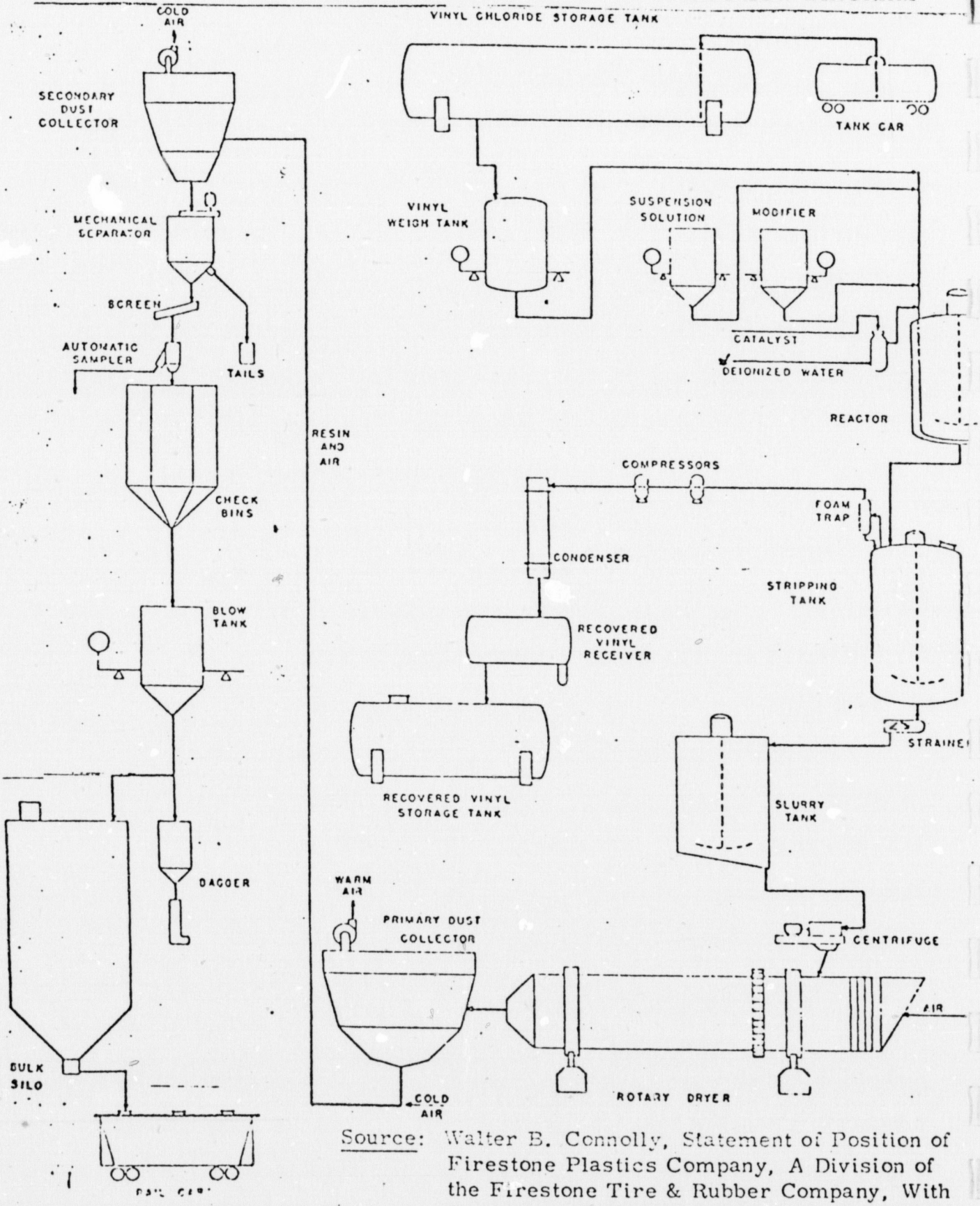
A more recently developed process is carried out in specially designed reactors in the absence of water and suspension additives. Because bulk resins are polymerized in a monomer matrix, the unused portion of which is recycled, they minimize contributing processing residues to the environment as pollutants. While capable of producing both general-purpose and specialty types of PVC, the bulk or mass polymerization process can also produce very porous PVC, the structure of which differs considerably from resins polymerized via suspension. Because PVC particles polymerized in bulk are free of additives used in suspension and emulsion polymerization, they lack membranous coatings. The excellent clarity inherent in bulk resins has made them preferred in many transparent product markets, including packaging film, bottles, and coatings.

Solution Polymerization[1]

A process of lesser commercial importance than the others discussed has been utilized in preparing specialty copolymers and terpolymers of vinyl chloride. Polymerization occurs in organic solvent which then must be usually removed and recovered. The solution polymers are generally higher priced and used in product applications such as coatings and adhesives.

Sources: (1) 1972-1973 Modern Plastics Encyclopedia, p. 104.
(2) 1973-1974 Modern Plastics Encyclopedia, p. 113.
(3) Snell.

REPRESENTATIVE POLYVINYL CHLORIDE SUSPENSION RESIN MANUFACTURE FLOW DIAGRAM



Source: Walter B. Connolly, Statement of Position of Firestone Plastics Company, A Division of the Firestone Tire & Rubber Company, With Respect to the Proposed Permanent Standard Dealing With Occupational Exposure to Vinyl Chloride to Occupational Safety and Health Administration, June 25, 1974.

EXHIBIT IV-8 (1)

USDOL/OSHA

TECHNOLOGICAL OVERVIEW OF SUSPENSION (S), EMULSION (E) AND CO-POLYMERIZATION (S & E TYPE)

Process Step	Process Where Used	Most Commonly Used Equipment	Less Commonly Used Equipment	Comments
(1) VCM Unloading	S, E, Co			Some plants have pipe line delivery with or without local storage.
	S, E, Co	Tank car	Barge	Tank cars: 10 to 38,000 gals.; Barges: Up to 300,000 gals.
	S, E, Co	Flexible hoses	Rigid pipe with flexible couplings	
	S, E, Co	Transfer pump		
	S, E, Co	Evaporator		Some low capacity plants are said to use nitrogen displacement for unloading. This practice can cause venting problems on return cars at the VCM plants, and at the unloading facility.
	S, E, Co	Evaporator feed pump		
	S, E, Co	Unloading compressor		
			Vacuum pump	Sometimes used to vent hoses prior to disconnect.
(2) VCM Storage		Hortonspheres	Horizontal tanks	Hortonspheres: 500-800,000 gals.; Tanks: Up to 80,000 gals. Sometimes storage is under refrigeration 15°C.
(3) VCM Transfer and Metering	S, E, Co	Transfer pump		
	S, E, Co	Day tank		Some plants particularly those using weigh tanks omit the day tank.
			Line strainer	Used occasionally.
	S, E, Co	Weigh tank and reactor	Metering tank and reactor	In copolymerization the other monomer is introduced here.
		Loading pump	Loading pump or metering pump	
	S, E, Co		Premix tank	Sometimes used.
	S, E, Co		Addition pot	Suspending agents and catalysts are sometimes premixed and added through a specially designed addition pot. Often ingredients are manually poured into the reactors.
(4) Polymerization	S, E, Co	Stirred reactor (polymerizer, autoclave)		Glass lined or stainless steel: From 2,000 to 5,000 gals. historically. New technology: To 35,000 gals. s. to 18,000 gals. G. L.
(5) Stripping	S, E, Co	Stripper	Blowdown tank	Stripping is sometimes carried out in the reactor, most simply through depressurization and monomer recovery. The use of steam jets is more advanced, while vacuum pumps are also used. Heating and steam sparging is sometimes practiced. Separate strippers at approximately twice the volume of the reactor are used. Developing technology is likely to feature multi-stage stripping using steam to reduce free monomer in the product and limit in-plant and dryer exhaust emissions.
(6) Monomer Recovery	S, E, Co	Foam knockout pot	Several pots in series	Monomer recovery is tied in to stripping.
	S, E, Co	Vacuum steam jet	And/or vacuum pumps	Jet exhaust is usually vented to atmosphere. Vacuum pump exhaust can go through monomer recovery unit.
	Co		Condenser	Most processors do not separate the comonomer but recycle the mixed
	Co		Comonomer separator	recovered stream.
		Reciprocating compressor	Rotary compressor	The most commonly used of the rotary compressors is the Nash water seal, said to have less maintenance problems than the reciprocating.
	S, E, Co	Condenser	Recovery still	Slight proprietary technological differences exist in the handling of the recovered monomer stream.
	S, E, Co	Recovered VCM tank		
	S, E, Co	Chilled vent condenser		
	S, E, Co	Recovered VCM pump		The recovered monomer is returned to the day or the weigh tank.

EXHIBIT IV-8 (2)

Process Step	Process Where Used	Most Commonly Used Equipment	Less Commonly Used Equipment	Comments
(7) Product Transfer	S, E, Co	Transfer pump		Some reactors are gravity dropped using flexible coupling or permanent piping.
	S, E, Co	Strainer	Filter or wet sifter	Basket strainers have been removed in some suspension plants. Open strainers sometimes used in emulsion plants require significant operator attention. Newer type strainers are equipped with backflush. In some installations, the straining equipment is spot vented.
	S, E, Co	Blend tank		Usually 2 to 5 times the size of the reactors. Sometimes open to the atmosphere (out-of-doors), usually vented, sometimes with blower and vent stack.
(8) Drying	S, E, Co			If a latex product is desired, steps 8, 9, and 10 are omitted.
	S, E, Co	Feed pump		Suspension slurry is 20 - 30% solids.
	S	Centrifuge		Usually continuous solid bowl.
	S	Wet cake conveyor		Wet cake contains about 30 - 35% water.
	E		Concentrator	Sometimes used before spary dryer. Usual wiped film type.
	E	Spray dryer	Coagulation tank	This equipment combination has been reported.
	E		Rotary vacuum filter	
	E		Apron dryer	
	S	Rotary dryer	Flash or fluid bed dryer	30,000 to 70,000 CFM of drying air. Final moisture: 0.2 - 0.5%.
(9) Product transfer and storage	S, E, Co	Dust collector		
	S, E, Co	Intermediate storage		For holding product while Q. C. tests are performed.
	S, E, Co	Pneumatic conveyor		There is a large variety of alternate types of equipment and configurations for the conveying of dry products. Several alternate systems exist in the same plant.
	S, E, Co	Grinder		
	S, E, Co	Dust collector		
	S, E, Co	Storage silos		
(10) Packaging and Shipping	S, E, Co	Bulk loading	Bagging	Bagging equipment is usually automatic or semi-automatic fluidized valve bag type
		Hopper cars	Tote bins	Bulk carriers sometimes use some form of fluidizing for unloading.
		Tank trucks		

Source: Shell analysis based on industry interviews.

EXHIBIT IV-9

USDOL/OSHA

THE POLYMERIZATION CYCLE IN THE SUSPENSION AND EMULSION PROCESSES

Cycle Step	Time	Most Common Practice	Alternate Practice	Comments
. Charging		Manway open, exhaust via "elephant hose".		In most plants the operator is in close proximity to the reactor during the charging operations. In most cases the displaced atmosphere is vented by means of the elephant hose during water fill.
- Water addition	10-20 minutes	Fill the reactor with the required amount of water. Usually by observing the level in the reactor on metering.	Sometimes the water is metered in with manway secured.	
- Ingredients addition	5 minutes	Add manually through open manway. Close the valves, secure the manway.	Premixed amounts dissolved or suspended in water are introduced to an addition pot.	A newer practice is to have the ingredients dissolved or suspended in appropriate weigh tanks and added through a manifold, sometimes with computerized controls.
- Monomer addition	10-20 minutes	Prior to monomer addition the reactor atmosphere is vented through a steam jet or a vacuum pump. The monomer is metered through a weigh tank or other metering device.	Sometimes, in addition, nitrogen is used either at atmospheric or under reduced pressure.	In some cases the ingredients, particularly the catalyst(s), are held in a specially designed addition pot. After monomer addition the atmosphere of the pot is connected with that of the reactor and the ingredient charge is dropped by gravity into the reactor.
. Reaction		Steam or hot water is admitted to the jacket to bring the temperature to 35-45°C.	Direct steam sparging into the reaction mixture.	
- Initiation	15-20 minutes			
- Cooling	5-20 hours	During the reaction, cold water is circulated through the jacket to carry away the heat evolved.	Sometimes the rate of circulation of the cooling water is adjusted by an automatic closed loop control.	
. Stripping (Blow down)	15-60 minutes	Some plants use only depressurization through the recovery unit, via foam knock-out pot, followed by steam jet.	Use vacuum pump at the end of depressurization, venting to the recovery system. A newer practice is to sparge steam to enhance the stripping and reduce the amount of free monomer going to the next steps.	Unreacted monomer is recovered either in the reactor itself or after transfer of the charge to a stripper or blow down tank.
. Reactor inspection	5-10 minutes	To determine that the reactor is empty.	Sometimes the manway is opened and residual material is hosed out of the reactor.	Newer automatic cleaning methods have been devised to eliminate the need to open the manway, or at least to minimize manual cleaning by a man entering the reactor.
. Cleaning	20 minutes to 4 hours	In most operations this is done every 3rd to 5th cycle.	Newer methods are used: - In-place water cleaning - Solvent cleaning	The most commonly used methods of automatic cleaning are described in Appendix A.
	1-1.5 hours	A man enters the reactor and chips or scrapes away the accumulated material. Since January 1974 the man is equipped with a fresh air breathing device while in the reactor, and wears protective clothing.	A man enters the reactor and uses a hand-held high pressure water hose.	Prior to entry and while the man is in the reactor the atmosphere of the tank is renewed through an exhaust system connected to an elephant hose. With reactors equipped with flexible connection the discharge hose is left open. With permanently connected reactor, a separate blower is lowered in the reactor to assist the air circulation in the reactor.

Source: Snell engineering assessment based on industry interviews.

EXHIBIT IV-10 (1)

USDOL/OSHA

POTENTIAL EXPOSURE CHECKLIST BASED ON SUSPENSION POLYVINYL CHLORIDE MANUFACTURE

1. Tank Farm (VCM Storage)

- Rail car unloading
  - Gasketing at hose connections
  - Pump seals*
  - Compressors*
  - Flanges at pipe joints
  - Valves*
  - Venting pressure off hoses before disconnecting
- Transfer operation (from storage tanks, to weight tanks)
  - Pipe flanges
  - Pump seals*
  - Valves*
  - Compressors*
  - Airing out tanks for pressure inspection or cleaning*

2. Polymerization - Reactor and Stripper Level

- Pump seals*
- Flanged pipe joints or vessel connections
- Reactor and stripper heads*
- Reactor and stripper seals
- Valves*
- Opening reactor and stripper heads for flushing*
- Flushing reactors and strippers*
- Cleaning reactors and strippers*
- Cleaning buildup from valves, lines, etc.*
- Maintenance on various pieces of equipment

2. Polymerization - Reactor and Stripper Level (continued)

- Airing out equipment in preparation for entry
- Operator errors*
- Plugged lines resulting in gasket failure*
- Ventilation of reactors during flushing operation (vapors discharged on roof)
- Airing out vessels containing poorly degassed material as a result of plugged discharge line, setup, etc.*
- Purging of reactors prior to charging (vapors discharged on roof)
- Purging of stripping vessels (vapors discharged on roof)

3. Polymerization Building - Pump Out Level (Relief Area)

- Pump seals
- Compressor*
- Leaking pipe flanges resulting in spills
- Leaks in VCM filtering vessels*
- Drains from top floor*
- Reclaim water containing dissolved vinyl chloride discharging inside building*
- Draining of foam traps on compressors*
- Draining water off the condensed recovered vinyl chloride*
- Moving polymer chips outside building and dumping drums
- Changing and handling VCM filters*

4. Blend Tank Area (Work-in-Process Storage)

- Monomer evolution during storage*
- Flushing blend tanks*
- Leaks (pump seals, hoses, pipe flanges)

5. Rotary Drying Operation

- Rotary dryer exhaust air
- Leaks from pump seals, pipe flanges
- Centrifuge liquid discharge (effluent)

5. Rotary Drying Operation (continued)

Any operation involving handling or storage of finished resin or where dried resin accumulates

- Bagging
- Housekeeping
- Dried product screening
- Changing dust collector bags
- Cleaning equipment
- Pneumatic transfer of resin to storage or into bulk trucks and rail cars
- Maintenance operations in areas where large masses of resin are stored, primarily silos •

6. Warehouse Area

- Space where resin is stored in a manner that restricts air circulation
  - Plastic shrouded pallets
  - Resin (and compound) in sealed drums or boxes, etc.
  - Resin (and compound) in semi-bulk containers (metal tote bins, etc.)
- Storage of resin in bags

7. Lab Area

- Testing of finished resin (and compound)
- Testing of resin slurry prior to drying (suspension resins)*
- Testing of VCM

* Likelihood of relatively greatest exposure.

Source: Firestone and Snell assessment.

EXHIBIT IV-11

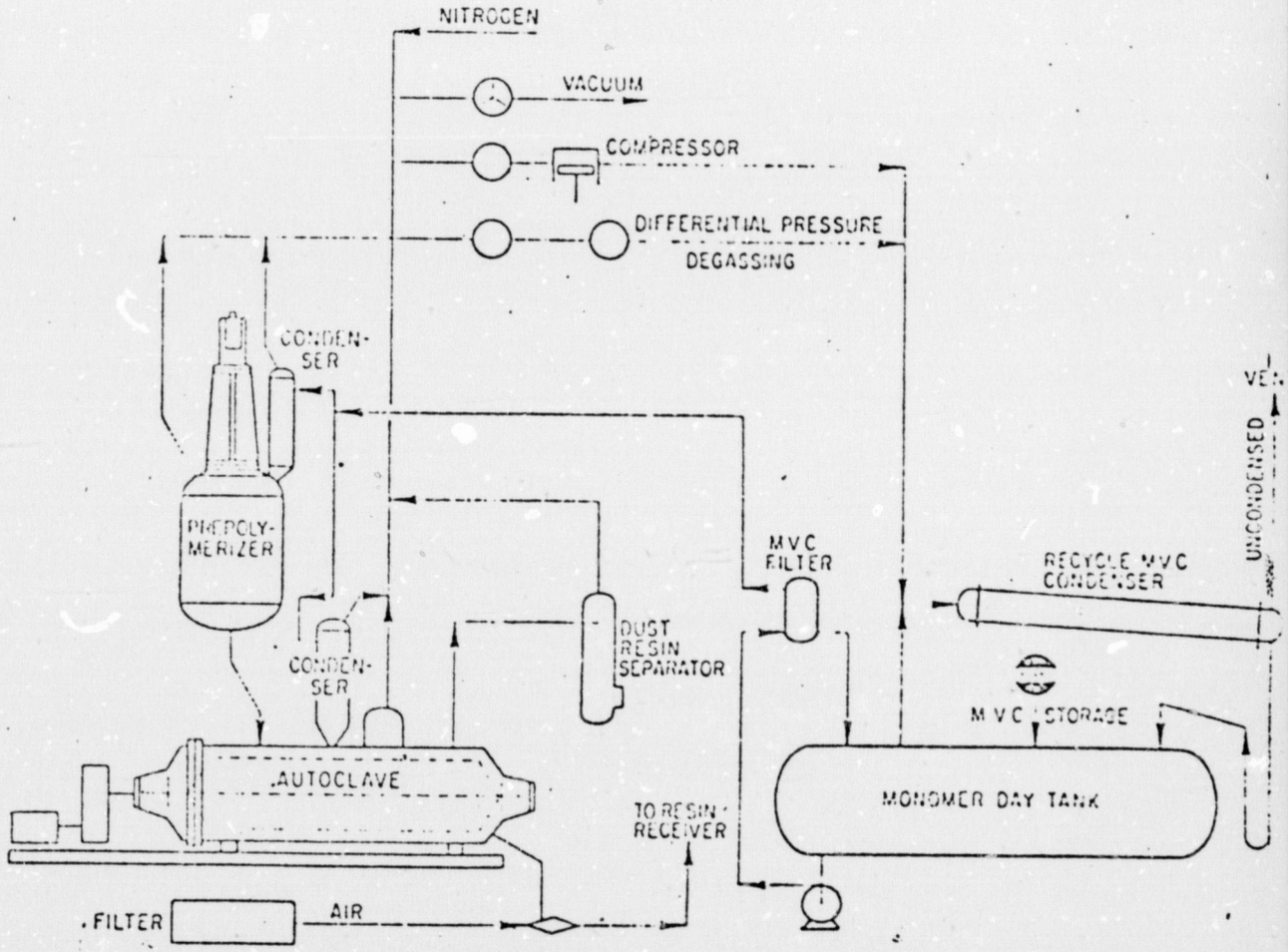
USDOL/OSHA

TYPICAL FLOW DIAGRAM FOR
THE BULK PROCESS

The two-step batch polymerization process carried out in two reactors in series. During the first step polymerization proceeds in a liquid medium of vinyl chloride monomer; it is a bead formation phase rate in the range of 10 to 12%. For this initial phase, a stainless clad, vertical autoclave equipped with very turbulent agitation is used. Operating pressure and agitation conditions set the particle size distribution and the shape of the bead used thereafter as a seed in the second step.

The second step is a growing phase for the seeds; it is performed in stainless clad autoclaves designed for efficient agitation of a powdery medium. At the end of the polymerization cycle the unreacted monomer is recovered by condensation and directly reused for further polymerization. PVC resin is then discharged from the horizontal autoclave to a classification unit which screens the product to the desired specification. Oversize amounting to 5-10% of total is reduced in size with an appropriate grinder designed not to affect the product properties.

Since mass process produces a dry free flowing resin prior to classification the normal capital expenditures associated in suspension PVC process for dewatering and drying are not necessary. The plant is run by a sequential program; the automatic control of operating procedures results in excellent reproductibility of products manufactured.



Source: Hydrocarbon Processing, November 1968, p. 193.

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EXHIBIT IV-12

USDOL/OSHA

OVERVIEW OF COPOLYMERIZATION

COPOLYMERS ARE MANUFACTURED BY THE SUSPENSION, THE EMULSION, OR THE SOLUTION PROCESS

Based on Exhibit III-16 data, copolymers represented 12% of PVC resin output in 1973. Copolymers are obtained by the simultaneous polymerization of vinyl chloride and up to 15-20% of other monomers such as vinyl acetate, vinylidene chloride and acrylics. The vinyl acetate copolymers are most important in terms of volume. The production processes differ only in details from the standard polymerization processes. Main points of difference are in the charging and recovery areas.

(1) Suspension And Emulsion Copolymerizations With Vinyl Acetate Are Carried Out In The Same Equipment As Used For Homopolymerization.

The only differences are the addition of a feed line from vinyl acetate storage tank to the monomer weigh tank and a slight modification to the recovery system as indicated below.

- Stripping of the unreacted monomers is carried out by venting the unreacted VCM to a recovery line modified to permit seperate recovery of the vinyl acetate. When most of the unreacted VCM has been vented to the recovery, steam is sparged through the slurry until a vapor steam containing VCM, vinyl acetate and a substantial amount of water vapor is obtained. The recovery line is equipped with two condensers in series upstream of the recovery compressor.

- A two phase system of liquid vinyl acetate and water is discharged from the bottom of the condensers. The vinyl acetate, seperated by decantation is returned to the process via the weigh tank and the water phase is discarded. Some processes are designed to recycle the mixed monomer stream back to the reaction without seperation.

(2) Copolymerizations Involving Vinylidene Chloride As A Comonomer Differ From Homopolymerizations In The Recovery Process

A separation column is usually incorporated in the recovery train to separate the unreacted vinylidene chloride. The column is designed to take advantage of the lower volatility of the vinylidene chloride (B.P.760=31.7°C). The recovered monomers are returned seperately to the process and the charges adjusted accordingly.

Source: Snell assessment based on industry interviews.

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EXHIBIT IV - 13 (1)

USDOL/OSHA

TYPICAL TIME REQUIREMENTS FOR IMPLEMENTING VARIOUS ENGINEERING CONTROL METHODS FOR POLYVINYL CHLORIDE PLANTS

Method	Rationale	Time to Complete
Major ventilation project	Increase rate of air changes in closed buildings	18 months
Minor ventilation	Install spot ventilation on a piece of equipment: pump, strainer, etc.	1/2 - 2 months
Venting of temporary tank car connection lines	Decrease release of VCM trapped between tank car valve, using vacuum and/or nitrogen flush	1 - 2 months
Installation of new gauging systems on tank car fleet	Eliminate the continuous emission of VCM which occurs with the dip tube system	12 - 24 months
Replacement or reconditioning of reactors (polys)	Reduce leakages at manholes, seals, etc.	18 - 24 months
Installation of solvent cleaning of reactors	Reduce need to clean manually	30 months
Installation of automatic water cleaning of reactors	(Alternative to solvent cleaning)	24 months
Additional stripping not requiring new steam generating facilities	Reduce VCM emissions downstream from the polymerization step	18 months
Additional stripping requiring new steam generating facilities	Reduce VCM emissions downstream from the polymerization step	36 months
Replacement of strainers	Eliminate open strainers and/or substitute closed self cleaning units	3 - 8 months

EXHIBIT IV - 13 (2)

USDOL/CSHA

TYPICAL TIME REQUIREMENTS FOR IMPLEMENTING VARIOUS ENGINEERING CONTROL METHODS FOR POLYVINYL CHLORIDE PLANTS

Method	Rationale	Time to Complete
Installation of rotary compressors to replace reciprocating compressors	Reduce VCM leakage during operation	18 months
Modifications to the piping	Reduce the number of flanged connections, etc.	1 - 12 months
Major processing change requiring R & D and demonstration	e.g. Change over from the batch to a continuous process	4 - 7 years
New plant construction	Install a complete redesigned facility	2.5 - 3 years

Sources: Snell's estimates based on interviews with producers, equipment manufacturers and engineering know-how

EXHIBIT IV-14
USDOL/OSHA

POLYVINYL CHLORIDE ECONOMICS[1] - 1974

Designed plant capacity (MM lb./year)	200
Plant investment (MM $)	20
Production (MM lb./year @ 90% utilization)	180
Plant investment per unit of production (¢/lb.)	11.1
Cost of Manufacture	¢/lb.
Vinyl chloride monomer (1.06 lb. @ 8¢/lb.)	8.5
Operating labor and supervision	0.4
Capital recovery (@ 12% - 10 years)	2.0
All other costs (catalysts, utilities, maintenance, etc.)	3.5
Total cost of manufacture	14.4
Profitability	
Net selling price (FOB plant)	18.6
Cost of manufacture	(14.4)
Selling, general and administrative expense	(1.5)
Pretax profit	2.7
Pretax return on total investment (@ 1.2 plant investment)	20%

(1) Grass roots plant, located on Gulf Coast, producing general purpose suspension resin, prior to the Emergency Temporary OSHA Standards.

Source: Snell estimates based on Milgrom, Jack: Incentives for Recycling and Reuse of Plastics. Washington, Environmental Protection Agency, 1972; industry interviews; and mid-1974 Chemical Marketing Reporter posted prices for monomer and polymer.

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V. FINDINGS AND ECONOMIC ANALYSIS

V. FINDINGS AND ECONOMIC ANALYSIS

This chapter presents the findings and economic analysis drawn from aggregation of plant-by-plant economic data, and the detailed data appearing in Chapters III and IV dealing with industry structure and technology respectively, as well as from the appendices.

Information is presented in individual sections topically addressing each of the key regulatory considerations of primary concern to the study (See Exhibit II-1). Sections follow as shown:

- VA - Economic Impact Assessment
- VB - Personal Protective Equipment Availability and Costs
- VC - Monitoring Equipment Availability and Costs
- VD - Medical Surveillance Costs
- VE - Exposure Data

VA. ECONOMIC IMPACT ASSESSMENT

This section presents the estimated economic impact of various regulatory standards on the vinyl chloride monomer (VCM) and polyvinyl chloride (PVC) industries. For this study, economic impact is defined only as the direct cost impact on the VCM and PVC industries resulting from compliance with proposed OSHA levels of VCM exposure. As shown in Exhibit II-1, study of economic impacts in other sectors and evaluation of PVC substitutability were not included in the scope of work. The specific study methodology employed and the indicators of economic impact are detailed in the respective discussions for the VCM and PVC industries.

1. METHODOLOGY FOR ESTIMATING THE ECONOMIC IMPACT IS BASED ON SNELL AUDITS OF INDUSTRY ASSESSMENTS OF REQUIRED ENGINEERING, PERSONAL PROTECTIVE AND MONITORING EQUIPMENT

- Information for assessing the economic impact under various VCM regulatory levels was collected through an industry survey conducted by Snell.

- The cost estimates are developed for various compliance levels.

  - plant-by-plant costs reported by industry for various VCM exposure levels provided the data base

  - individual plant information was aggregated to provide the estimated impact per pound of VCM or PVC produced for the industry

- Cost estimates of specified equipment were checked by Snell for order of magnitude validity.

- monitoring and personal protective equipment information were compared with equipment supplier quotations

- specific items such as compressors, pumps, etc. were validated with supplier quotations

- Major cost items for the required engineering steps were reviewed by Snell engineers to determine their accuracy.

- Exhibit V-1, on the following page, summarizes the economic impact indicators used.

2. FINDINGS FROM ECONOMIC IMPACT ANALYSIS RELATED TO THE VCM INDUSTRY ARE BASED ON SUBSTANTIAL DATA TO A TARGET LEVEL OF 10 PPM VCM CEILING AND 2 - 5 TWA

- Snell assessed industry costs of reducing VCM levels in VCM plants were separated into five categories which include:

  - engineering costs, including:

    .. ventilation
    .. vapor recovery
    .. stripping (product purification)
    .. loading for shipping
    .. other (pumps, piping, etc.)

EXHIBIT V-1
USDOL-OSHA
ECONOMIC IMPACT INDICATORS
USED FOR THE STUDY

Indicator	Definition	Comments
• Estimated Industry Costs of Achieving Various VCM Target Levels	• Based on capacity weighted aggregation of industry reported costs audited by Snell	• Expressed as unit capital and annual costs in Exhibits V-2 to V-4 for VCM and Exhibits V-7 to V-10 for PVC
- Engineering) - Personal Protective Equipment) - Monitoring and Other) - Productivity Loss	• These are defined in the text of the Economic Impact Assessment for VCM and PVC plants, respectively • Productivity loss is the cost of additional capacity needed to maintain industry-wide capacity at levels unimpacted by OSHA regulations	• Exhibit C-3 in Appendix C provides further explanation of productivity loss • Based on data for the plant sample at each level
• Price Impact Analysis	• The impact of the costs of compliance relative to a standard unimpacted price element	• Does not consider potential shifts in supply/demand configurations • See Exhibits V-13 and 14 for VCM and PVC, respectively
• Industry Claimed Time to Reach VCM Target Levels	• Analysis of the distribution of the times claimed for each plant	• See Exhibits V-5 and V-11 for VCM and PVC, respectively
• Percent of Industry "Endangered" As A Function of Target Levels	• The level at which management will seriously consider plant shutdown based on distribution of industry responses	• Actual decisions to shut down plants are based on a complex set of factors plant-by-plant • See Exhibits V-6 and V-12 for VCM and PVC, respectively
• Change in Emphasis of Engineering Controls in PVC Plants As A Function of Target Levels	• Analysis of the distribution of the major categories of engineering action in the industry responses	• See Exhibit V-17 and Exhibit C-5 in Appendix C.

Source: Snell

- personal protective equipment costs, including:

  .. shower and eating facilities
  .. breathing equipment (respirators, air lines and bottled air)
  .. clothing (uniforms and protective clothing)

- monitoring costs, including:

  .. personnel monitoring equipment
  .. area and leak monitoring equipment
  .. medical testing
  .. record keeping

- productivity loss

  .. the continued cost of keeping at the levels unimpacted by OSHA capacity otherwise derated as a result of regulation

  .. the cost includes equipment, personnel, etc. but does not include the costs of temporary shutdowns

- expensed items

  .. these include consultant costs, management time, etc.

  .. out-of-pocket expenses of 0.01¢/lb are not included since these are considered as one time only costs

For VCM plants, engineered OSHA compliance steps are judged to be significantly the same as those for air pollution control.

Summarized estimates of VCM industry cost impacts and timing to meet selected VCM compliance levels follow in Exhibits V-2 through V-6.

- Exhibit V-2 presents the case of the 50 ppm VCM ceiling
- Exhibit V-3 presents the case of the 25 ppm ceiling
- Exhibit V-4 presents the case of the 10 ppm ceiling and 2 to 5 ppm TWA (time weighted average)
- Snell assessment in these Exhibits of VCM levels potentially achieved is based upon the exposure data in Section VE and Appendix B
- Exhibit V-5 presents the industry claimed time requirements for compliance
- Exhibit V-6 serves as a summary discussion of these findings

EXHIBIT V-2

USDOL/OSHA

ESTIMATED INDUSTRY COSTS OF ACHIEVING A 50 PPM VCM CEILING LEVEL IN VCM PLANTS AS CLAIMED BY INDUSTRY AND ASSESSED BY SNELL

Snell assessment of VCM level potentially achieved(1) less than 50 ppm ceiling with 15 ppm TWA.
Total plants in sample: 9
Processes represented(2): O, STO, DO, DC, G
Location of plants in sample(3): 8W, 1C

Capacity in Sample - Millions lbs. per year (Percent 1974 U. S. nameplate capacity): 5,125 (77%)
Percent Industry claimed capacity from sample for which management will seriously consider plant shutdown at a 50 ppm ceiling VCM level: 0%
Snell estimate of percent capacity from sample for which management will seriously consider plant shutdown at a 50 ppm ceiling VCM level: 0%

Direct Costs	Capital ($/1,000 lb.)	Annual ($/1,000 lb.)	Percent of Total Annual Cost
I. Engineering Costs(4)	$0.66	$0.29(5)	43%
II. Personal Equipment Costs(6)	0.03	0.02(7)	2
III. Monitoring	0.08	0.13(7,8,9)	19
Total Direct Costs(10)	$0.77	$0.44	64%
Productivity Loss	$0.16	$0.24	36%
Total Costs	$0.93	$0.68	100%

Note:
(1) Snell estimate of VCM levels achieved in plants incorporating the level of control effort represented in the Exhibit. Monitoring data is detailed in Appendix B.
(2) O = Oxychlorination, STO = Stauffer Oxychlorination, DO = Dow Oxycholorination, DC = Direct Chlorination, G = Goodrich Oxychlorination.
(3) W = Sited in warm climate, C = Sited in cold climate.
(4) Includes ventilation, vapor recovery, stripping, loading and other (piping, general pumps, maintenance, etc.)
(5) Includes capital amortized @ 12% - 10 yrs. and O&M charges.
(6) Includes breathing equipment and clothing.
(7) Includes capital amortized @ 12% - 5 yrs. and O&M charges.
(8) Includes area and personal monitoring equipment.
(9) Includes medical and recordkeeping costs.
(10) Productivity loss is the industry average cost of additional capacity, personnel, etc. to maintain industry capacity levels unimpacted by OSHA regulations, an example is provided in Exhibit C-3.

Source: Industry interviews and Snell estimates.

EXHIBIT V-3

USDOL/OSHA

ESTIMATED INDUSTRY COSTS IN ACHIEVING A 25 PPM VCM CEILING LEVEL IN VCM PLANTS AS CLAIMED BY INDUSTRY AND ASSESSED BY SNELL

Snell assessment of VCM level potentially achieved(1) 25 ppm ceiling with 15 ppm TWA.
Total plants in sample: 7(2)
Processes represented(3): O, STO, DO, DC, G
Location of plants in sample(4): 8W, 1C

Capacity in Sample - Millions lbs. per year (Percent 1974 U.S. nameplate capacity): 3,625 (54%)
Percent Industry claimed capacity from sample for which management will seriously consider plant shutdown at a 25 ppm ceiling VCM level: 0%
Snell estimate of percent capacity from sample for which management will seriously consider plant shutdown at a 25 ppm ceiling VCM level: 0%

Direct Costs	Capital ($/1,000 lb.)	Annual ($/1,000 lb.)	Percent of Total Annual Cost
I. Engineering Costs(5)	$1.72	$0.69(6)	58%
II. Personal Equipment Costs(7)	0.05	0.04(8)	3
III. Monitoring	0.17(9)	0.21(8, 9, 10)	17
Total Direct Costs	$1.94	$0.94	78%
Productivity Loss(11)	$0.18	$0.26	22%
Total Costs	$2.12	$1.20	100%

Notes:
(1) Snell estimate of VCM levels achievable in plants incorporating the level of control effort represented in the Exhibit. Monitoring data is detailed in Appendix B.
(2) Two plants not in this cost sample did not report cost estimates for a 25 ppm VCM ceiling target but provided an analysis for a lower target VCM level.
(3) O = Oxychlorination, STO = Stauffer Oxychlorination, DO = Dow Oxychlorination, DC = Direct Chlorination, G = Goodrich Oxychlorination.
(4) W = Sited in warm climate, C = Sited in cold climate.
(5) Includes ventilation, vapor recovery, stripping, loading and other (piping, general pumps, maintenance, etc.).
(6) Includes capital amortized @ 12% - 10 yrs. and O&M charges.
(7) Includes breathing equipment and clothing.
(8) Includes capital amortized @ 12% - 5 yrs. and O&M charges.
(9) Includes area and personal monitoring equipment.
(10) Includes medical and recordkeeping costs.
(11) Productivity loss is the industry average cost of additional capacity, personnel, etc. to maintain industry capacity levels [illegible] by [illegible] regulations, [illegible] Exhibit V-3. [illegible]

Source: Industry interviews and Snell estimates.

EXHIBIT V-4

USDOL/OSHA

ESTIMATED INDUSTRY COSTS OF ACHIEVING A 10 PPM VCM TARGET CEILING AND 2-5 PPM TWA LEVELS IN VCM PLANTS AS CLAIMED BY INDUSTRY AND ASSESSED BY SNELL

Snell assessment of VCM level potentially achieved(1). Same as industry claimed.
Total plants in samples: 9
Processes represented(2): O, STO, DO, DC, G
Location of plants in sample(3): 8W, 1C

Capacity in Sample - Millions lbs. per year (percent 1974 U.S. nameplate capacity): 5,125 (77%)
Percent industry claimed capacity from sample for which management will seriously consider plant shutdown at a 10 ppm ceiling and 2-5 ppm TWA VCM level: 0%
Snell estimate of percent capacity from sample for which management will seriously consider plant shutdown at a 10 ppm ceiling and 2-5 ppm TWA VCM level: 0%

Direct Costs	Capital ($/1,000 lb.)	Annual ($/1,000 lb.)	Percent of Total Annual Cost
I. Engineering Costs(4)	$3.68	$1.44(5)	45%
II. Personal Equipment Costs(6)	0.09	0.07(7)	2
III. Monitoring	0.22(8)	0.24(7,8,9)	7
Total Direct Costs	$3.99	$1.75	54%
Productivity Loss(10)	$1.04	$1.46	46%
Total Costs(11)	$5.03	$3.21	100%

Notes: (1) Snell estimate of VCM levels achievable in plants incorporating the level of control effort represented in the Exhibit. Monitoring data is detailed in Appendix B.
(2) O = Oxychlorination, STO = Stauffer Oxychlorination, DO = Dow Oxychlorination, DC = Direct chlorination, G = Goodrich Oxychlorination.
(3) W = Sited in warm climate, C = Sited in cold climate.
(4) Includes ventilation, vapor recovery, stripping, loading and other (piping, general pumps, maintenance, etc.).
(5) Includes capital amortized @ 12% - 10 yrs. and O&M charges.
(6) Includes breathing equipment and clothing.
(7) Includes capital amortized @ 12% - 5 yrs. and O&M charges.
(8) Includes area and personal monitoring equipment.
(9) Includes medical and recordkeeping costs.
(10) Productivity loss is the industry average annual cost of additional capacity, personnel, etc. to maintain capacity levels unimpacted by OSHA regulations. An example is provided in Exhibit C-3.
(11) Cost estimates include analysis for two plants with a reported 2 ppm VCM TWA (8 hr.) level.

Source: Industry interviews and Snell estimates.

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EXHIBIT V-5

USDOL/OSHA

U.S. INDUSTRY CLAIMED TIME TO REACH SELECTED VCM LEVELS
IN VCM PLANTS THROUGH ENGINEERED CONTROLS

VCM Target Level Claimed by Industry	Sample Total		End of Year									
			1974		1975		1976		1977		1978	
	Number of Plants	Capacity (Million Lbs.)	Number of Plants	Percent[1] Capacity	Number of Plants	Percent[1] Capacity	Number of Plants	Percent[1] Capacity	Number of Plants	Percent[1] Capacity	Number of Plants	Percent[1] Capacity
50 ppm ceiling	9	5,125	9	100%								
25 ppm ceiling	7[2]	3,625	1	7			6	93%				
10 ppm ceiling and 2 - 5 ppm TWA	9	5,125					3	49	5	46%	1	5%

Notes: (1) Percent of sample 1974 capacity.

(2) Two plants did not report cost estimates for a 25 ppm VCM ceiling target, but provided an analysis for a lower target VCM level.

Source: Industry interviews by Snell.

EXHIBIT V-6

USDOL/OSHA

SUMMARY OF VCM INDUSTRY COST IMPACTS, COMPLIANCE TIME AND CAPACITY ENDANGERED

VCM Target Level Claimed by Industry	Snell Assessment of VCM Target Level	Annual Unit Costs, ¢/Lb.(1) Direct Costs of Compliance	Costs To Make Up for Loss of Productivity	Total Costs(2)	Industry Claimed Compliance Period Required for Engineered Controls	Percent of Industry "Endangered"(3) Based on Sample
50 ppm ceiling	< 50 ppm ceiling and 15 ppm TWA	0.04¢	0.03¢	0.07 ± 10%	In compliance now	0%
25 ppm ceiling	25 ppm ceiling and 15 ppm TWA	0.09	0.03	0.12 ± 20%	2 years	0%
10 ppm ceiling with 2 - 5 ppm TWA	10 ppm ceiling and 2 - 5 ppm TWA	0.17	0.15	0.32 ± 40%	3 years	0%
"No detectable"			Not feasible based on engineering controls.			100%

Notes: (1) Costs at each VCM level represent the cumulative costs incurred to reach the target level.
(2) The percentage ranges of total costs represent Snell's estimates.
(3) Endangered = Management will seriously consider plant shutdown.

Source: Exhibits V-1 through V-5.

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3. FINDINGS FROM ECONOMIC IMPACT ANALYSIS RELATED TO THE PVC INDUSTRY ARE BASED ON SUBSTANTIAL DATA TO A TARGET LEVEL OF 15 - 25 PPM VCM CEILING AND 10 - 15 PPM TWA

Snell assessed industry costs of reducing VCM levels in PVC plants were separated into five categories which include:

- engineering costs including:
  - VCM unloading
  - ventilation
  - reactor cleaning
  - stripping and VCM recovery (possibly to meet a 100 ppm residual VCM target, but definitely to facilitate meeting the PVC industry exposure target level)
  - other (pumps, piping, etc.)
- personal protective equipment costs, including:
  - showers and eating facilities
  - breathing equipment (respirators, air lines and bottled air)
  - clothing (uniforms and protective clothing)

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- monitoring costs, including:

  .. personnel monitoring equipment
  .. area and leak monitoring equipment
  .. medical testing
  .. record keeping

- productivity loss

  .. the continued cost of keeping at the levels unimpacted by OSHA capacity otherwise derated as a result of regulation

  .. the cost includes equipment, personnel, etc. but does not include the costs of temporary shutdowns

- expensed items

  .. these include consultant costs, management time, etc.

  .. out-of-pocket expenses of 0.033¢/lb are not included in the cost summaries since these are considered to be one time only expenses.

Summarized estimates of PVC industry cost impacts and timing to meet selected VCM concentration levels follow in Exhibits V-7 through V-12.

- Exhibit V-7 presents the case of the 50 ppm VCM ceiling

- Exhibit V-8 presents the case of the 25 to 40 ppm ceiling and 15 to 25 ppm TWA

- Exhibit V-9 presents the case of the 15 to 25 ppm ceiling and 10 to 15 ppm TWA

- Exhibits V-7, V-8, V-9 follow page V-7

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EXHIBIT V-7

USDOL/OSHA

ESTIMATED INDUSTRY COSTS OF ACHIEVING A 50 PPM TARGET VCM CEILING LEVEL
IN PVC PLANTS AS CLAIMED BY INDUSTRY AND ASSESSED BY SNELL

Snell assessment of VCM level potentially achieved[1]. Same as industry claimed.
Total plants in sample: 23
Processes represented[2]: S, E, B, SO
Location of plants in sample[3]: 5W, 18C

Age of plants in sample:	Range, Years	0 - 5	6 - 10	11 - 15	16 - 20	21 - 25	> 26
	No. of Plants	2	10	2	4	2	3

Capacity of sample - millions lbs. per year (percent 1974 U.S. nameplate capacity): 3,750 (69%)
Percent industry claimed capacity from sample for which management will seriously consider plant shutdown at a 50 ppm VCM ceiling: 0%
Snell estimate of percent capacity from sample for which management will seriously consider plant shutdown at a 50 ppm VCM ceiling: Negligible

Direct Costs	Capital ($/1,000 Lb.)	Annual ($/1,000 Lb.)	Percent of Total Annual Cost
I. Engineering Costs[4]	$1.69	0.93[5]	17%
II. Personal Equipment Costs[6]	0.16	0.23[7]	4
III. Monitoring	0.70[8]	0.74[7,8,9]	14
Total Direct Costs	$2.55	$1.90	35%
Productivity Loss[10]	$6.53	$3.48	65%
Total Costs	$9.08	$5.38	100%

Notes: (1) Snell estimate of VCM levels achieved in plants incorporating the level of control effort represented in the Exhibit. Monitoring data is detailed in Appendix B.
(2) S = Suspension, E = Emulsion, Dispersion, B = Bulk, SO = Solution.
(3) W = Sited in warm climate, C = Sited in cold climate (U.S. 26C, 10W).
(4) Includes ventilation, loading, reactor cleaning, stripping and other (piping, general pumps, maintenance, etc.).
(5) Includes capital amortized @ 12% - 10 yrs. and O&M charges.
(6) Includes breathing equipment and clothing.
(7) Includes capital amortized @ 12% - 5 yrs. and O&M charges.
(8) Includes area and personal monitoring equipment.
(9) Includes medical and recordkeeping costs.
(10) Productivity loss is the industry average annual cost of additional capacity, personnel, etc. to maintain industry capacity levels unimpacted by OSHA regulations; an example is shown in Exhibit C-3.

Source: Industry interviews and Snell estimates.

EXHIBIT V-8

USDOL/OSHA

ESTIMATED INDUSTRY COST OF ACHIEVING A 25-40 PPM VCM TARGET CEILING AND 15-25 PPM TWA LEVEL IN PVC PLANTS AS CLAIMED BY INDUSTRY AND ASSESSED BY SNELL

Snell assessment of VCM level potentially achieved[1] same as industry claimed
Total plants in sample: 17[2]
Processes represented[3]: S, E, B
Location of plants in sample[4]: 5W, 12C

Age of plants in sample:	Range, Years	0 - 5	6 - 10	11 - 15	16 - 20	21 - 25	> 26
	No. of Plants	2	8	1	3	2	1

Capacity in Sample - Millions lbs. per year (Percent 1974 U.S. nameplate capacity): 2,801 (52%)
Percent Industry claimed capacity from sample for which management will seriously consider plant shutdown at a 25-40 ppm ceiling and 15-25 ppm TWA VCM level: ≈ 4% of original 23 plant sample

Direct Costs	Capital ($/1,000 lb.)		Annual ($/1,000 lb.)		Percent of Total Annual Cost	
I. Engineering Costs[5]	$7.18		$2.19[6]		26%	
II. Personal Equipment Costs[7]	1.01		0.70[8]		8	
III. Monitoring	0.67[9]		0.76[8,9,10]		9	
Total Direct Cost	$8.86		$3.65		43%	
Productivity Loss[11]		$9.38		$4.87		57%
Total Costs		$18.24		$8.52		100%

Notes:
(1) Snell estimate of VCM levels achievable in plants incorporating the level of control effort represented in the Exhibit. Monitoring data is detailed in Appendix B.
(2) Four plants not in this cost sample did not report cost estimates for these conditions but provided an analysis for a lower target VCM level. Two plants not in this sample did not provide cost estimates for this and lower levels; one reported being endangered, the other had not completed an analysis.
(3) S = Suspension, E = Emulsion, Dispersion, B = Bulk, SO = Solution.
(4) W = Sited in warm climate, C = Sited in cold climate (U. S. 26C, 10W).
(5) Includes ventilation, loading, reactor cleaning, stripping and other (piping, general pumps, maintenance, etc.).
(6) Includes capital amortized @ 12% - 10 yrs. and O&M charges.
(7) Includes breathing equipment, clothing, showers, and eating facilities.
(8) Includes capital amortized @ 12% - 5 yrs. and O&M charges.
(9) Includes area and personal monitoring equipment.
(10) Includes medical and recordkeeping costs.
(11) Productivity loss is the industry average cost of additional capacity, personnel, etc. to maintain industry capacity levels unimpacted by OSHA regulations, excluding plants which reported inability to meet the standard. An example is presented in Exhibit C-3.

Source: Industry interviews and Snell estimates.

EXHIBIT V-9

USDOL/OSHA

ESTIMATED INDUSTRY COST OF ACHIEVING A 15-25 PPM VCM CEILING AND 10-15 TWA PPM TARGET LEVEL IN PVC PLANTS AS CLAIMED BY INDUSTRY AND ASSESSED BY SNELL

Snell assessment of VCM level potentially achieved(1). Same as industry claimed.
Total plants in sample: 16(2)
Processes represented(3): S, E, B
Location of plants in sample(4): 4W, 12C

Age of plants in sample:	Range, Years	0 - 5	6 - 10	11 - 15	16 - 20	21 - 25	26
	No. of Plants	1	7	1	3	2	2

Capacity in sample - millions lbs. per year (percent 1974 U.S. nameplate capacity): 2,600 (48%)
Percent industry claimed capacity from sample for which management will seriously consider plant shutdown at a 25 ppm ceiling and 10-15 ppm TWA VCM level: 20% of original 23 plant sample
Snell estimate of percent capacity from sample for which management will seriously consider plant shutdown at a 25 ppm ceiling and 10-15 ppm TWA VCM level: 20% of original 23 plant sample

Direct Costs	Capital ($/1,000 Lb.)	Annual ($/1,000 Lb.)	Percent of Total Annual Cost
I. Engineering Costs(5)	$26.44	$7.30(6)	45%
II. Personal Equipment Costs(7)	0.48	0.76(8)	5
III. Monitoring	0.86(8)	0.95(8,9,10)	6
Total Direct Costs	$27.78	$9.01	56%
Productivity Loss(11)	$14.41	$7.03	44%
Total Costs	$42.19	$16.04	100%

Notes: (1) Snell estimate of VCM levels achieved in plants incorporating the level of control effort represented in the Exhibit. Monitoring data is detailed in Appendix B.
(2) The four plants not included in Exhibit V-8 provided cost estimates for this VCM target level. Five additional plants not in this cost sample reported endangered status at this level and did not provide cost estimates.
(3) S = Suspension, E = Emulsion, Dispersion, B = Bulk, SO = Solution.
(4) W = Sited in warm climate, C = Sited in cold climate.
(5) Includes ventilation, loading, reactor cleaning, stripping and other (piping, general pumps, maintenance, etc.)
(6) Includes capital amortized @ 12% - 10 yrs.
(7) Includes breathing equipment, clothing, showers, and eating facilities
(8) Includes capital amortized @ 12% - 5 yrs.
(9) Includes area and personal monitoring equipment.
(10) Includes medical and recordkeeping costs.
(11) Productivity loss is the industry average annual cost of additional capacity, personnel, etc. to maintain industry capacity level, unimpacted by OSHA regulations. This is based on those plants that expected ability to meet the claimed level, shown in the Exhibit. An example is presented in Exhibit C-3.

Source: Industry interviews and Snell estimates.

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- At these levels (particularly at the high VCM target levels) engineering controls reported by industry principally addresses OSHA compliance but substantial air pollution control is judged to be an indirect benefit from "buttoning-up" of the plant, improved stripping, etc.

- Snell assessment in these Exhibits of VCM levels potentially achieved is based upon the exposure data in Section VE and Appendix B

- Exhibit V-10 provides cost analyses based on data provided by Firestone for an attempt to reach "no detectable" target VCM levels primarily using engineering controls

  .. Firestone was the only PVC producer reporting an analysis related to a "no detectable" VCM standard primarily using engineering controls

  .. Firestone concluded that meeting a "no detectable" standard primarily using engineering controls is not feasible

  .. The two Firestone plants were not included in the industry summaries for higher VCM target levels based on the findings from the statistical analysis presented in Exhibit C-4 in Appendix C for the 50 ppm ceiling target; at this level Firestone cost estimates are inconsistently high with respect to those provided by therest of the industry, possibly because these estimates include costly environmental protection measures not directly related to OSHA compliance.

- Exhibit V-10 follows page V-8.

EXHIBIT V-10

USDOL/OSHA

COST ANALYSES BASED ON DATA PROVIDED BY FIRESTONE FOR AN ATTEMPT TO REACH "NO DETECTABLE" TARGET VCM LEVELS USING ENGINEERING CONTROLS PRIMARILY

Snell assessment of VCM level potentially achieved(1). This represents an analysis of an attempt to approach "no detectable" levels with actually achieving the level judged not feasible, based on engineering controls primarily.
Total plants in sample: 2 (Pottstown, Pa. and Perryville, Md.)
Process represented(2): S and E
Location of plants in sample(3): 2C

Age of plants in sample: Range, Years 0 - 5 | 6 - 10 | 11 - 15 | 16 - 20 | 21 - 25 | >26

Plants: Perryville, Pottstown

Capacity of plant - millions lbs. per year (percent 1974 U.S. capacity): 507 (9%)

Direct Costs	Capital: Pottstown, Pa. ($/1,000 lb.)	Capital: Perryville, Md. ($/1,000 lb.)	Annual: Pottstown, Pa. ($/1,000 lb.)	Annual: Perryville, Md. ($/1,000 lb.)	Two Plant Average: Capital ($/1,000 lb.)	Two Plant Average: Annual ($/1,000 lb.)
I. Engineering(4)	$142.56	$55.94	$53.60(5)	$25.79(5)	$88.40	$36.21
II. Personal Equipment(6)	8.19	0.32	1.88(7)	1.81(7)	3.27	1.84
III. Monitoring	3.85(8)	1.29(8)	3.20(7,8,9)	1.40(7,8,9)	2.25	2.07
Total Direct Costs	$154.60	$57.55	$58.68	$29.00	$93.92	$40.12
Productivity Loss(10)	$139.84	$30.35	$67.05	$15.79	$63.52	$30.66
Total Costs	$294.44	$87.90	$125.73	$44.79	$157.44	$70.78

Notes: (1) Snell estimates of VCM levels achievable in plants incorporating the level of control effort represented in the Exhibit.
(2) S = Suspension, E = Emulsion, Dispersion.
(3) W = Sited in warm climate, C = Sited in cold climate.
(4) Includes ventilation, loading, reactor cleaning, stripping and other (piping, general pumps, maintenance, etc.)
(5) Includes capital amortized @ 12% - 10 years and O&M charges.
(6) Includes breathing equipment and clothing.
(7) Includes capital amortized @ 12% - 5 years and O&M charges.
(8) Includes area and personal monitoring equipment.
(9) Includes medical and recordkeeping costs.
(10) Productivity loss is the industry average annual cost of additional capacity, personnel, etc. to maintain industry capacity levels unimpacted by OSHA regulations; an example is presented in Exhibit C-3.

Source: Firestone Case I (0-1 ppm VCM level) presentation to June 1974 OSHA hearing and Snell estimates of costs of productivity loss.

- Exhibit V-11 presents the PVC industry claimed time requirements for compliance, following page V-9

- Exhibit V-12, following Exhibit V-11, serves as a summary discussion of these findings

4. INCREASINGLY STRICT VCM COMPLIANCE REQUIREMENTS ARE EXPECTED TO RESULT IN SIGNIFICANTLY GREATER PRICE ESCALATIONS FOR PVC THAN FOR VCM

. Price analysis did not include consideration of supply/demand changes due to potential plant shutdowns at lower levels.

. The price analyses are relative to a standardized price pro forma unimpacted by OSHA compliance requirements and assess price sensitivity of OSHA compliance steps based substantially upon engineering controls.

. Exhibit V-13, following Exhibit V-12, presents the estimated impact of selected VCM standards on VCM prices.

. Exhibit V-14, following Exhibit V-13, presents the estimated impact of selected VCM standards on PVC prices.

. Exhibit V-15, following Exhibit V-14, presents estimated capital and annual costs for VCM target levels for the VCM industry.

. Exhibit V-16, following Exhibit V-15, presents estimated capital and annual costs for VCM target levels for the VCM industry.

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EXHIBIT V-11

USDOL/OSHA

U. S. INDUSTRY CLAIMED TIME TO REACH SELECTED VCM LEVELS IN PVC PLANTS THROUGH ENGINEERED CONTROLS(1)

VCM Target Levels Claimed By Industry	End of Year									
	1974		1975		1976		1977		1978	
	Number of Plants	Percent Capacity	Number of Plants	Percent Capacity	Number of Plants	Percent Capacity	Number of Plants	Percent Capacity	Number of Plants	Percent Capacity
50 ppm ceiling	23	100%								
25 - 40 ppm ceiling and 15 - 25 ppm TWA	-	-	1	3%	7	35%	12	48%	1	5%
15 - 25 ppm ceiling and 10 - 15 ppm TWA	-	-	-	-	5	24%	7	27(1)	4	18%
Attempt to reach "No detectable"	Not feasible based on engineering controls									

Notes: (1) Percent of sample 1974 capacity, 23 plants reporting with a total capacity of 3,750 million lbs. per year.

Source: Industry interviews by Snell

EXHIBIT V-12

USDOL/OSHA

SUMMARY OF PVC INDUSTRY COST IMPACTS, COMPLIANCE TIME AND CAPACITY ENDANGERED BY VCM TARGET LEVEL

VCM Target Level Claimed by Industry	Annual Unit Costs, ¢/Lb.(1)			Industry Claimed Compliance Period Required for Engineered Controls	Percent of Industry "Endangered"(3) Based on Sample
	Direct Costs of Compliance	Costs To Made Up for Loss of Productivity	Total Costs(2)		
50 ppm ceiling	0.19	0.35	0.54 ± 20%	0 to 6 months	Negligible(4)
25 - 40 ppm ceiling with 15 - 25 TWA	0.36	0.49	0.85 ± 35%	2.5 years	4%
15 - 25 ppm ceiling with 10 - 15 TWA	0.90	0.70	1.60 ± 50%	2.5 years	26%
Attempt to reach "No detectable"(5)	4.01	3.07	7.08 ± 75%	2.5 to 4 years	100%

Notes: (1) Does not include additional VCM costs resulting from OSHA standard.

(2) The percentage ranges of total costs represent Snell's estimates based on partial statistical analysis of data.

(3) Endangered = Management will seriously consider plant shutdown.

(4) Temporary shutdowns for installation of controls were reported. In addition, one plant (not in sample) accelerated a planned shutdown by six months resulting in a loss of ≈50 million lbs. of PVC.

(5) Economic data based on average data shown in Exhibit V-10 for the Firestone plants which were not included in the sample for the reason explained in the text. These figures represent the costs estimated for an attempt to reach a "no detectable" VCM level, but reaching this level is judged not feasible based on engineering controls.

Source: Exhibits V-7 through V-11.

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EXHIBIT V-13

USDOL/OSHA

ESTIMATED VINYL CHLORIDE ECONOMICS IMPACTED BY SELECTED VCM LEVEL STANDARDS
(1974 DOLLARS)

Item	Unimpacted by OSHA (¢/Lb.)	50 ppm Ceiling (¢/Lb.)	25 ppm Ceiling (¢/Lb.)	10 ppm Ceiling 2 - 5 ppm TWA (¢/Lb.)	Extrapolated Costs of Attempt To Reach a VCM Level[2]
Plant investment[1]	4.08¢	4.16	4.27	4.48	11.58¢
Cost of manufacture	6.13	6.17	6.27	6.31	9.63
Selling, general and administrative expenses	0.30	0.30	0.30	0.30	0.30
Pretax profit on total investment @ 20% at 1.2 x plant investment)	0.98	1.00	1.02	1.08	2.78
Net selling price (FOB plant)	7.41¢	7.47¢	7.59¢	7.69¢	12.71¢

Notes: (1) Unit production costs for a 500 million lb. ethylene oxychlorination plant of 1974 construction with total fixed capital of $20.4 million unimpacted by OSHA costs include production loss replacement.

(2) Based on log-log straight line extrapolation of existing data to a 1 ppm VCM ceiling. This does not imply technical feasibility of engineering controls. Extrapolated costs are for attempting to reach a "no detectable" level and are used for cost sensitivity analyzing purposes only.

Source: Exhibit IV-4 for basic economics and Snell estimates for compliance levels based on Exhibits V-1 through V-4.

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EXHIBIT V-14

USDOL/OSHA

POLYVINYL CHLORIDE ECONOMICS IMPACTED BY
SELECTED VCM LEVEL STANDARDS
(1974 DOLLARS)

Item VCM Standard PVC Standard	Unimpacted by OSHA	50 ppm Ceiling 50 ppm Ceiling	50 ppm Ceiling 25-40 ppm Ceiling 15-25 ppm TWA	25 ppm Ceiling 25-40 ppm Ceiling 15-25 ppm TWA	25 ppm Ceiling 25 ppm Ceiling 10-15 ppm TWA	10 ppm Ceiling 2- 5 ppm TWA 15-25 ppm Ceiling 10-15 ppm TWA	Extrapolated Costs To Attempt To Reach a "No Detectable" VCM Level(1) Firestone Analysis of Attempt To Reach "No Detectable" VCM Level(2)
Designed PVC plant capacity (millions lbs./year)	200	200	200	200	200	200	200
PVC plant investment (dollars millions)(3)	20	21.6	23.3	23.3	27.6	27.6	48.7
PVC production (millions lbs./year @ 90% utilization)	180	180	180	180	180	180	180
Plant investment per unit of production (¢/lb.)	11.1	12.0	12.9	12.9	15.3	15.3	27.0
Cost of Manufacture							
Vinyl chloride monomer(4)	8.5¢	8.5¢	8.5¢	8.6¢	8.6¢	8.7¢	12.7¢
Operating labor and supervision	0.4						
Capital recovery (@ 12% - 10 years)	2.0	6.4	6.6	6.6	7.5	7.5	13.0
All other costs (catalysts, utilities, maintenance, etc.)	3.5						
Total cost of manufacture	14.4¢	14.9¢	15.1¢	15.2¢	16.1¢	16.2¢	25.7¢
Profitability							
Cost of manufacture	14.4¢	14.9¢	15.1¢	15.2¢	16.1¢	16.2¢	25.7¢
Selling, general and administrative	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Pretax profit (@ 20% x 1.2 plant investment)	2.7	2.9	3.1	3.1	3.7	3.7	6.5
Net selling price (FOB plant)	18.6¢	19.3¢	19.7¢	19.8¢	21.3¢	21.4¢	33.7¢

Notes: (1) Based on log-log, straight line extrapolation of existing data to a 1 ppm VCM ceiling. This does not imply technical feasibility of engineering controls. Extrapolated costs are for attempting to reach a "no detectable" level and are used for cost sensitivity analysis purposes only.

(2) Based on Firestone data presented in Exhibit V-10. These figures represent the costs estimated for an attempt to reach a "no detectable" VCM level, but reaching this level is judged not feasible based on engineering controls primarily.

(3) Gram room plant, located on Gulf Coast, producing general purpose suspension resin.

(4) VCM at price shown on Exhibit V-12 x 1.06 production shrinkage + 0.5¢/lb. transport.

Source: Snell estimates based on industry interviews and prices for VCM presented in Exhibit V-13.

EXHIBIT V-15
USDOL/OSHA
ESTIMATED CAPITAL AND ANNUAL COSTS FOR VCM TARGET LEVELS FOR THE VCM INDUSTRY AT 1974 CAPACITY (1)
(1974 DOLLARS)

Industry Claimed VCM Target Level (2)	Snell Assessed VCM Target Level (3)	Capital Costs (4) ($ Millions)			Annual Costs (4, 5) ($ Millions)		
		Direct Costs	Productivity Loss	Total	Direct Costs	Productivity Loss	Total
50 ppm ceiling	<50 ppm ceiling and 15 ppm TWA	$ 5.2	$ 1.1	$ 7.2	$ 3.0	$ 1.6	$ 4.6
25 ppm ceiling	25 ppm ceiling and 15 ppm TWA	13.0	1.2	14.2	6.3	1.7	8.0
10 ppm ceiling and 2-5 ppm TWA	10 ppm ceiling and 2 - 5 ppm TWA	26.7	7.0	33.7	11.7	9.8	21.5

(1) 1974 capacity estimated at 6,695 million lbs. per year in Exhibit III-1

(2) Compliance actions are based primarily on engineering control methods

(3) Based upon the exposure data in Section VE and Appendix B

(4) Estimates include costs of engineering controls, personal protective and monitoring equipment. Costs presented represent the estimated cumulative compliance costs for the VCM level shown in the Exhibit and were estimated by multiplying the costs presented in Exhibits V-2 through V-4 by the 1974 VCM industry capacity.

(5) Includes capital costs amortized at 12%

Source: Industry interviews and Snell estimates

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EXHIBIT V-16
USDOL/OSHA
ESTIMATED CAPITAL AND ANNUAL COSTS FOR VCM TARGET LEVELS FOR THE PVC INDUSTRY AT 1974 CAPACITY(1)
(1974 DOLLARS)

Industry Claimed and Snell Assessed VCM Target Level (2, 5)	Capital Costs (3) ($ Millions)			Annual Costs (3, 4) ($ Millions)		
	Direct Costs	Productivity Loss	Total	Direct Costs	Productivity Loss	Total
50 ppm ceiling	$13.9	$ 35.5	$ 49.4	$ 10.3	$18.9	$29.2
25-40 ppm ceiling and 15-25 ppm TWA	48.1	51.0	99.1	19.8	26.5	46.3
15-25 ppm ceiling and 10-15 ppm TWA	151.0	78.3	229.0	49.0	38.2	87.2

(1) 1974 capacity estimated at 5,435 million lbs. per year from Exhibit III-4.

(2) Compliance actions are based primarily on engineering control methods.

(3) Estimates include costs of engineering controls, personal protective and monitoring equipment. Costs presented represent the estimated cumulative compliance costs for the VCM levels shown in the Exhibit and were estimated by multiplying the costs presented in Exhibits V-7 through V-9 by the 1974 PVC industry capacity.

(4) Includes capital costs amortized at 12%.

(5) If the PVC industry expended the capital funds represented by the Firestone analysis of attempting to reach the infeasible "no detectable" levels, total capital costs are estimated to be of the order of $856 million based on Exhibit V-10 data.

Source: Industry interviews and Snell estimates

5. SHIFTS IN ENGINEERING CONTROL METHODS WERE REPORTED FOR DECREASING VCM TARGET LEVELS IN THE PVC INDUSTRY

- Exhibit V-17 on the following page summarizes the distribution of engineering controls for selected VCM levels.

- Exhibit C-5 in Appendix C provides a detailed discussion of the distribution of engineering controls for selected VCM levels.

* * * * *

This section presented economic impact details. The next section discusses personal protective equipment.

EXHIBIT V-17 (1)

USDOL/OSHA

SUMMARY OF THE DISTRIBUTION OF REPORTED
ENGINEERING CONTROL METHODS ESTIMATED FOR
SELECTED VCM LEVELS IN POLYVINYL CHLORIDE PLANTS

Engineering Control Method	Comments for 50 ppm Ceiling; 25-40 ppm Ceiling with 15-25 ppm TWA; and 15-25 ppm Ceiling with 10-15 ppm TWA
VCM Unloading (1)	• Modification to transport equipment may be completed by VCM supplier
Ventitation (2)	• Ventilation is used at all levels • Substantial costs are estimated to reach all target levels • Most plants have ventilation at the 50 ppm level
Reactor Cleaning (3)	• 5 of 19 plants install reactor cleaning equipment for the 50 ppm level • Most plants have reactor cleaning for the 25-40 ppm ceiling with 15-25 ppm TWA target level
Stripping (4-5)	• Three plants report expenditures > $380,000 at the 50 ppm ceiling level, probably for new systems • Seven plants report expenditures > $70,000 to reach a 25-40 ppm ceiling with 15-25 ppm TWA target level. These expenditures represent improvement to existing equipment. Three plants estimate expenditures > $350,000, probably for new systems. • At the 15-25 ppm ceiling with 10-15 ppm TWA 7 plants report expenditures > $1 million, for R&D and new systems.
Other (6)	• Extensive modification to physical plant are estimated for all levels. • At 15-25 ppm VCM ceiling with 10-15 ppm TWA expenditures of > $400,000 are estimated for such items as emergency reactor pressure relief systems (to VCM recovery) and computerized control systems.

Notes follow (Exhibit V-17 (2)

Notes:

(1) Fans, ducting, etc.

(2) Additions to unloading racks, modifications to VCM piping, unloading pumps and compressors.

(3) High and low pressure water systems and solvent cleaning systems.

(4) Tanks, pumps, piping, compressors and condensers.

(5) At the 50 ppm and 25 ppm ceiling levels stripping expenditures generally address improvements to present system to meet in plant requirements. The much larger expenditures at the 15-25 ppm ceiling and 10-15 ppm TWA levels reflect an effort to also improve the residual free monomer levels in the product.

(6) Non specific pumps, compressors piping, seals, etc.

Source:

Industry Interviews and Snell estimated from Exhibit C-5.

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VB. PERSONAL PROTECTIVE EQUIPMENT AVAILABILITY AND COSTS

This section presents the estimated costs, the procurement lead times, and a summary of the available types of equipment as required by the proposed permanent standard.

1. TWO OF THE FOUR TYPES OF RESPIRATORS LISTED UNDER THE PROPOSED PERMANENT STANDARD (PPS) ARE READILY AVAILABLE FROM AT LEAST ONE EQUIPMENT MANUFACTURER

   . Two of the types of OSHA listed respirators are normally available from the manufacturer in approximately 60 days from the placement of the order. These types are:

   - pressure demand full-facepiece self-contained breathing apparatus (PD)

   - combination pressure demand full-facepiece respirator and pressure demand self-contained breathing apparatus (CPD)

   . If sudden orders were placed for 500 to 700 of these units, a 60 day lead time is quoted by one supplier but another indicated up to 40 weeks.

   . The two other types of breathing apparatus listed in the PPS are not currently produced. Interviews with manufacturers indicate that these devices are considered wasteful of compressed air. These types are:

   - positive pressure full-facepiece self-contained breathing apparatus

   - combination continuous flow respirators and a pressure demand self-contained breathing apparatus.

2. THE REQUIRED TYPES OF RESPIRATORS PURCHASED UNDER THE 50 PPM TEMPORARY STANDARD MAY BE USED UNDER LOW VCM CEILING CONCENTRATIONS

   . The purchase costs for types PD and CPD from exhibit D-8 are $515 and $615, respectively.

- The operating and maintanance costs from Exhibit D-10 range between $500 to $1,000 per man per year, with an average of data estimated at $900.

- For example, the cost of grade D or better breathable air is $15 per 310 SCF cylinder. With an air flow of 4 CFM, this amounts to a cost of $0.20/minute.

3. INDUSTRY AND THE EMPLOYEES PREFER HALF-MASK AIR LINES, CANISTER OR CARTRIDGE TYPE RESPIRATORS OVER THOSE REQUIRED BY OSHA IN THE PPS

- Industry and worker preferences and human factors are detailed in Exhibits D-1 through D-4.

- Self-contained devices are heavy, bulky, and require highly trained individuals.

- Air line respirators are much lighter than self-contained, but they require a long hose for the air supply and a complicated air distribution system.

- Cartridge and canister types are the lightest and least expensive of the three, but lifetime has not yet been fully established for atmospheres containing VCM.

- Users of cartridge or canister type masks have no way of knowing when their air purifier is no longer effective.

- Half-face mask types are more comfortable to wear than those with full-facepieces, however, they do not provide complete facial protection.

4. THE NUMBER OF COVERED WORKERS NEEDING RESPIRATORY PROTECTION INCREASES WITH A DECREASE IN PERMISSIBLE VCM CONCENTRATION LEVELS OR REQUIRE HIGHER RESPIRATORY WEARING TIMES

The following table summarizes case studies of the percentage of workers needing respiratory protection as a function of VCM permissible levels, climate of plant location, and plant type (VCM or PVC). More data appears in Exhibit D-11 of Appendix.

Plant Type	Climate of Plant Location	Ceiling VCM Level (ppm)	Percent Of Workers Needing Respiratory Protection	Percent Of Time Respiratory Protection Needed	Comments
VCM	Warm	50	15%	50%	With Engineering Controls
		25	15	50	With Engineering Controls
		10	30	75	Without Engineering Controls
		10	14	50	With Engineering Controls
		1	100	100	With Engineering Controls
PVC	Warm	50	75	1	With Engineering Controls
		25	100	3	With Engineering Controls
		10 ppm TWA +25 ppm ceiling	100	25	With Engineering Controls
		1	NA	NA	With Engineering Controls
	Cold	50	100	10	Without Engineering Controls
		25	100	25	Without Engineering Controls
		1	100	100	Without Engineering Controls

Source: Exhibit D-11 and Snell Assessment

5. MOST OF THE TYPES OF PROTECTIVE CLOTHING ARE AVAILABLE WITHIN FOUR WEEKS FROM ORDER PLACEMENT

- Disposable clothing, hoods, shoe covers, gloves and overalls are available within one week from the manufacturers including one piece pressurized suits, as shown in Exhibit D-9.
- Permanent (reusable) work clothing is also available within one month of order.
- Full impervious pressurized suits however, have a procurement lead time of at least two months.

6. COSTS FOR PROTECTIVE CLOTHING VARY WITH TYPE, WITH A LOW OF $3.50 FOR DISPOSABLE CLOTHING TO A HIGH OF $178 FOR A PERMANENT, IMPERVIOUS,FULL PRESSURIZED SUIT

- A full suit of disposable clothing including coveralls, hoods, shoe covering, and gloves costs approximately $3.50.

- Permanent work clothing costs in the neighborhood of $40.00 per worker for a full suit of clothing including coveralls, gloves and boots.

- A permanent impervious full pressurized work suit which can be worn with an air mask costs $178. Industry believes that routine use of these is not feasible on grounds of human factors, indicated in Exhibit D-5 and concluded from the Snell industry interviews.

- The cost of cleaning a suit of permanent work clothes is in the range of $1.00 to $1.50 per suit, per worker, per day.

* * * * *

The next section deals with monitoring equipment.

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VC. MONITORING EQUIPMENT AVAILABILITY AND COSTS

This section summarizes the available types of VCM monitoring equipment, their costs, and procurement lead times needed to determine worker VCM exposure under the provisions of the proposed permanent standard.

1. THE THREE MAJOR CLASSES OF VCM MONITORING DEVICES: PERSONAL, AREA, AND LEAK, ARE ALL AVAILABLE TO THE VCM AND PVC PRODUCING INDUSTRIES

- Personal monitoring, which is the technique recommended to OSHA by NIOSH (see Exhibit E-3), is available to industry from the manufacturer within two months from time of order. The gas chromatograph needed for the analysis of their samples can be received from the manufacturer in two to three months time.

- Area monitoring systems of the automatic sequential or continuous type can be obtained for installation within six months from time of order. Installation could take upwards of two months.

- Manual area monitoring systems comprising a gas chromatograph with a flame ionization detector (FID) and Mylar or Tedlar bags for sample collection can be obtained from the manufacturer within three months. These devices require little or no set-up time.

- Leak detection devices such as portable gas chromatographs or infrared spectrophotometers can be received from suppliers within two months.

- If demand for these devices suddenly increase, it is Snell's judgment that procurement lead times could double, especially for the more sophisticated types of equipment such as the area monitoring systems.

2. THE COSTS OF MONITORING EQUIPMENT RANGE WIDELY DEPENDING ON TYPE, HOWEVER, MOST EQUIPMENT PURCHASED UNDER THE TEMPORARY 50 PPM STANDARD MAY BE USED AT LEVELS DOWN TO AND BELOW ONE PPM VCM

- Personnel monitoring equipment vary in cost from $300 for automated charcoal tube/pump system to $70 for colorimetric tube devices. For the automated system, a back-up gas chromatograph is required at a cost upwards of $7,000 including basic chromatograph, columns, recorder, and mechanical integrator as shown in Appendix Exhibit D-5.

  Area monitoring systems of the sequential gas chromatograph type cost in the neighborhood of $12,000 per 10 point instrument system without installation. Those operating under the FID total hydrocarbon principle can be purchased for $8,000, again without installation charges.

- Leak detection equipment, which are either of the portable gas chromatograph, total hydrocarbon FID, and infrared types cost from $3,000 to $5,000. No installation is required for these devices.

3. EXPENDITURES FOR MONITORING EQUIPMENT FOR A TYPICAL VCM OR PVC PLANT AVERAGE $100,000 IN CAPITAL WITH ANNUAL OPERATING EXPENSES OF $80,000

- Personal monitoring equipment of the colorimetric types do not require a chemist for back-up due to their instantaneous reading capability. The charcoal tube types, however, require a trained chemical technologist for analysis of samples due to the necessity of using a gas chromatograph. At least one chemist per plant is needed at an annual cost of $15,000 to $20,000. Overhead, general and administrative and chemical costs in support of the chemist could approximately double his annual cost.

- The cost of installation for automated sequential or continuous area monitoring systems is approximately $15,000 per 10 point unit with operating and maintenance costs of about $30,000 per year with an operator. A mini-computer can be interfaced with the system for alarming and recordkeeping for an additional $10,000 to $15,000 and O&M costs of $4,000 per year.

- Leak detection devices cost in the area of $2,000 to $3,000 for O&M including a part-time operator for each instrument.

4. THE INDUSTRY AS A WHOLE SHOWS NO PREFERENCE FOR PARTICULAR TYPES OF MONITORING EQUIPMENT, ALTHOUGH THE CONCEPT OF AREA MONITORING APPEARS WELL ACCEPTED

- The VCM and PVC producing industries employ a variety of different types of monitoring equipment in each classification.

- In personal monitoring, both the colorimetric and charcoal tube system are employed. However, the charcoal tube type are sensitive to lower VCM concentrations than colorimetric devices.

- For area monitoring, both gas chromatographs (GC) and total hydrocarbon analyzers and combustion conductivity detectors are used.

  - gas chromatographs provide concentration values which are specific for vinyl chloride monomer

  - total hydrocarbon analyzers, as their name suggests, are not specific for VCM but give the total hydrocarbon concentration in the sample air.

  - combustion conductivity detectors have also shown great utility in VCM detection at low concentration levels.

5. AUTOMATIC SEQUENTIAL MONITORING SYSTEMS (ASMS) CAN SERVE AS A LONG TERM DATA COLLECTION SYSTEM FOR AN ENTIRE PLANT

- The ASMS can analyze an air sample from a particular point in the plant in 1 to 3 minutes with potential for at least 10 point monitoring.

- A system installed in the polymerization building can provide warning to work personnel in that area if VCM levels have gone above ceiling levels.

- Personal monitoring data can provide the statisitical basis for locating sampling points for the ASMS.

  - TWAs can be determined by the personnel monitors for critical areas

  - these values can provide a calibration for the ASMS and determine the points within an area where the greatest VCM exposures are most likely to occur.

- The ASMS can be used to provide correlation with personnel monitoring data of actual worker exposure. In addition, it can be used to provide a permanent record of VCM levels, provide alarms in case of exceeding ceiling values, serve as a means to initially identify the general sources of VCM releases, and to monitor progress in complying with OSHA requirements.

6. THE AUTOMATIC SEQUENTIAL MONITORING SYSTEM CAN PROTECT WORKERS AND ALERT MAINTENANCE PERSONNEL WHEN EXCESSIVE VCM CONCENTRATIONS OCCUR

- VCM emissions can occur from two sources:

  - slowly developing minor continuous leakage, such as a worn pump seal

- serious leakage, such as resulting from an operating error (e.g. valve left fully or partially open) or a serious sudden leak (e.g. blown gasket, sight glass breakage, etc.)

In both cases, the system can prove useful in alarming the potentially affected people.

- In the case of a minor leak however, (with localized effects) the sample point nearest the leak will register the localized concentration and alarm on the next sampling indicating localized concentration above the limit.

- Response to either type of alarm can be standardized. These steps could include donning of personal protective equipment, investigation using leak detectors, isolating the point of VCM release and corrective maintenance.

* * * * *

The next section deals with medical surveillance costs.

V.D. MEDICAL SURVEILLANCE COSTS

This section presents the annual costs to industry for medical surveillance essentially based on the NIOSH recommendations to OSHA.

1. THE AVERAGE TIME REQUIRED PER EMPLOYEE FOR THE REQUIRED MEDICAL EXAMINATION IS FOUR HOURS WHEN PERFORMED OUTSIDE THE PLANT

From the information presented in the Appendix Exhibit F-2, the time allowance per employee is itemized as follows:

- Travel to and from examination facility -- 2.5 hours
- Examination and laboratory tests - 1.5 hours
- Maximum time required - 4 hours or 1/2 working day

2. THE SNELL ESTIMATE FOR TOTAL EXAMINATION COST PER EMPLOYEE IS $160

- The cost estimate developed by Snell is based primarily on the tests and examination procedures recommended to OSHA by NIOSH as detailed in Exhibit F-3.
- The costs were estimated for examination and tests completed outside the plant for a manufacturing facility with 500 covered workers. The total cost for such a plant would be approximately $82,000/year.

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3. INDUSTRY ESTIMATES OF THEIR PRESENT MEDICAL SURVEILLANCE COSTS AVERAGE $140 PER WORKER PER YEAR

It was assumed by Snell that the examinations performed by the reporting plants were based on the NIOSH recommendations to OSHA.

35.18

VE. VINYL CHLORIDE EXPOSURE DATA

This section presents the analyses of ambient air monitoring data taken under the Emergency Temporary Standard and supplied to Snell by industry and OSHA. In addition, the limitations of these data are discussed together with the summary of probable worker exposure for both monomer and PVC plants.

1. INDUSTRY AND OSHA SUPPLIED DATA ARE LIMITED, HOWEVER, THEIR ANALYSES BY SNELL PROVIDED AN INDICATION OF AVERAGE VCM LEVELS FOR THE MONOMER AND PVC PLANTS

The following points describe the data limitations:

- Sample locations for area monitoring or spot sampling within the plants are not clearly identified. However, the data allowed general association with job classifications.

- The measuring techniques employed for the OSHA data were 10 minute Sippin pump carbon tube samples with a total ambient air volume collection of 1 liter. Industry data were collected by organic vapor analysers (OVA), bag samples, charcoal tube pumps, or area monitoring. Some of the data levels represent averages of individual samples gathered at random time intervals.

- In general, Snell did not receive raw data from industry, but rather the averages of individual data points without data point statistics (i.e., No. of individual data points, mean, standard deviation, etc.). The OSHA data submitted to Snell are in terms of individual data points, but these are not related to job classifications or unit operations.

- In both the industry and OSHA cases, the data population is small.

- The data base is judged inadequate to quantitatively differentiate suspension polymerization from emulsion polymerization which are the main processes of the PVC industry.

- Snell arranged the available data in two major categories

  - VCM Plants
  - PVC Plants

- The available data were averaged and then correlated to the various job classifications. The data presented average levels of VCM for individual plants which were then used to develop an industry-wide profile of average VCM concentrations.

2. IN PVC PLANTS THE HIGHEST EXPOSURE OCCURS IN JOB CLASSIFICATIONS DIRECTLY INVOLVED IN THE MANUFACTURE OF PVC; WITH VCM LEVELS AVERAGING APPROXIMATELY 15 PPM ACCORDING TO DATA SUBMITTED TO SNELL BY INDUSTRY

The following table summarizes the average VCM levels by job classification as presented in Exhibit B-22 in Appendix B.

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	Range PPM		
	Average	High	Low
I. Production			
VCM Unloading			
VCM Unloaders	16	40	6
PVC Processing			
Supervisors	10	22	5
Senior Reactor Operators	9	20	1
Reactor Operators	17	30	5
Chargers	19	70	7
Stripper Operators	35	90	5
Centrifuge Operators	NA	120	3
Dryer Operators	13	51	1
Utility Men (Cleaners, Laborers, etc.)	25	78	6
Baggers	7	20	1
Warehouse	9	20	1
Overall Production	16	-	-
II. Maintenance	24	92	2
III. Laboratory			
Professionals	NA	6	1
Technicians	63	184	1
Overall Laboratory	42	-	-
IV. Management & Support	< 1	2	< 1

Source: Exhibit B-22

3. ANALYSIS OF THE MONITORING DATA SUBMITTED TO SNELL BY THE PVC PRODUCING INDUSTRY INDICATES THAT 92% OF AVERAGE MEASUREMENTS HAD VALUES OF 50 PPM VCM OR LESS

As summarized in Exhibit B-23

3% of averages had values of 1 ppm or less
22% of averages had values of 5 ppm or less
58% of averages had values of 10 ppm or less
67% of averages had values of 15 ppm or less
75% of averages had values of 20 ppm or less
80% of averages had values of 25 ppm or less
83% of averages had values of 30 ppm or less
84% of averages had values of 40 ppm or less
92% of averages had values of 50 ppm or less

4. ANALYSIS OF THE MONITORING DATA TAKEN BY OSHA AT PVC PLANTS AND CONFIDENTIALLY SUBMITTED TO SNELL INDICATES THAT 93% OF ALL SPOT SAMPLES HAD VALUES OF 50 PPM; WITH VCM LEVELS AVERAGING APPROXIMATELY 14 PPM

As summarized in Exhibit B-24

3% of samples had values of 1 ppm or less
46% of samples had values of 5 ppm or less
56% of samples had values of 10 ppm or less
64% of samples had values of 15 ppm or less
72% of samples had values of 20 ppm or less
76% of samples had values of 25 ppm or less
79% of samples had values of 30 ppm or less
86% of samples had values of 35 ppm or less
90% of samples had values of 45 ppm or less
93% of samples had values of 50 ppm or less

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Overall, agreement exists between the OSHA data and those submitted by industry to Snell. However, the OSHA data contains approximately twice as many more values, on a percentage basis, in the range of 5 ppm or less. The OSHA data do not specify the unit operations or job classifications associated with each reading.

5. ANALYSIS OF THE MONITORING DATA TAKEN BY OSHA AT VCM PLANTS AND CONFIDENTIALLY SUBMITTED TO SNELL INDICATES THAT 96% OF ALL SPOT SAMPLES HAD VALUES OF 35 PPM OR LESS; WITH VCM LEVELS AVERAGING APPROXIMATELY 8 PPM

From Appendix B-108

15% of samples had values of 1 ppm or less
62% of samples had values of 5 ppm or less
77% of samples had values of 10 ppm or less
84% of samples had values of 15 ppm or less
89% of samples had values of 20 ppm or less
94% of samples had values of 25 ppm or less
96% of samples had values of 35 ppm or less

6. INDUSTRY AND OSHA DATA INDICATE THAT AVERAGE VCM CONCENTRATIONS IN PVC PLANTS ARE LESS THAN 50 PPM FOR THE FOUR BROAD JOB CLASSIFICATIONS

The following table summarizes PVC industry-wide VCM average exposure levels as a function of broad job classifications in relation to industry employment in each worker category.

Broad Job Classification	Approximate 1974 Number of Workers	Percent of Total	Average of Concentration
Production (1)	3,030	55%	16
Maintenance (1)	1,350	24	24
Laboratory	390	7	42
Management and Support (2)	805	14	1
Total (3)	5,575	100%	15 (4)

Notes: (1) Includes line supervisors, such as foremen
(2) Includes plant managers, engineering staff, clerical, etc.
(3) Personnel associated with compounding and fabrication in integrated facilities are not included
(4) Average VCM concentration for all job classifications

Sources: Exhibit III-10, B-22, and Snell assessment of data.

7. INDUSTRY AND OSHA DATA INDICATE THAT AVERAGE VCM CONCENTRATIONS IN VCM PLANTS ARE LESS THAN 10 PPM FOR THE FOUR BROAD JOB CLASSIFICATIONS

The following table summarizes VCM industry-wide average VCM exposure levels as a function of broad job classifications in relation to industry employment in each worker category.

Broad Job Classification	Approximate 1974 Number of Workers	Percent of Total	Average VCM Concentration
Production (1)	410	44%	4
Maintenance (2)	250	27	2
Laboratory	60	6	4
Management and Support (2)	220	23	1
Total	940	100%	3 (3)

Notes: (1) Includes line supervisors, such as foremen
(2) Includes plant managers, engineering staff, clerical, etc.
(3) Average VCM concentration for all job classifications

Sources: Exhibits III-3, B-107, and Snell assessment of data.

* * *

Based on the assessment of the limited data supplied to Snell be industry and OSHA, it appears that average VCM concentrations for the four broad job classifications in both the VCM and PVC producing industry are below 50 ppm. Furthermore, the average VCM concentration in vinyl chloride plants is in the range of 3 to 8 ppm while for PVC plants the average concentration is approximately 15 ppm.

The next chapter provides conclusions and recommendations.

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VI. CONCLUSIONS AND RECOMMENDATIONS

VI. CONCLUSIONS AND RECOMMENDATIONS

This chapter addresses the conclusions and recommendations of the report based on the findings and economic analysis of the previous section.

1. ACHIEVING "NO DETECTABLE" LEVELS OF VCM PRINCIPALLY THROUGH ENGINEERING MEANS IS JUDGED NOT FEASIBLE WITH PRESENT TECHNOLOGY BOTH IN THE VCM AND PVC SECTORS

- Based on the industry surveys and Snell's independent assessments of the state-of-the-art of the technology, it is concluded that achieving "no detectable" (0 - 1 ppm) VCM levels in the VCM industry is not feasible principally through engineering means. Reasons include the following:

  - technology, including state-of-the-art developments, is not available to eliminate VCM leaks and fugitive losses

  - existing plants have not been designed for total VCM containment

  - there is no design or operating experience in the industry aimed at maintaining very low VCM levels

  - no direct technology transfer opportunities are known to enable development of designs for "no detectable" levels in new plants.

- Based on the industry surveys and Snell's independent assessments of the state-of-the-art of the technology, it is concluded that achieving "no detectable" (0 - 1 ppm) VCM levels in the PVC industry is not feasible principally through engineering means. Reasons include the following:

  - PVC manufacture is a batch operation

  - Technology, including state-of-the-art developments is not available to eliminate VCM leaks and fugitive losses

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- existing plants have not been designed for total VCM containment
- there is no design or operating experience in the industry aimed at maintaining very low VCM levels
- no direct technology transfer opportunities are known to enable development of designs for "no detectable" levels in new plants.

. Up to four years of development is estimated to reduce residual VCM levels below 100 ppm in PVC products on the basis of output volume.

. The technology including state-of-the-art developments is not available to reach very low or "no detectable" residual VCM levels on the basis of output volume.

2. THE COSTS OF COMPLIANCE INCREASE RAPIDLY WITH DECREASING VCM TARGET LEVELS AND REPRESENT SIGNIFICANT ENGINEERING UNCERTAINTY OR INFEASABILITY BEYOND 10 PPM CEILING AND 2 - 5 PPM TWA FOR THE VCM INDUSTRY AND 15 - 25 PPM CEILING AND 10 - 15 TWA FOR THE PVC INDUSTRY

. The analysis which follows indicates the cost sensitivity of attempting to reach very low VCM levels in the VCM industry.

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VCM Target Level (ppm)	Standard Price (¢/lb.)	Price Index	Percent of VCM Industry Capacity Endangered	Time To Reach Level Via Engineering Controls (years)
Historical Practice	7.41	1.00	Not Applicable	Not Applicable
50 ceiling	7.47	1.01	0%	0.5
25 ceiling	7.59	1.02	0%	2.5
10 ceiling and 2-5 TWA	7.69	1.04	0%	3.0
Extrapolated Attempt to Reach "No Detectable" Levels	12.71	1.72	100% @ "No Detectable" Levels	Not Estimated

Source: Exhibits V-15 and V-13

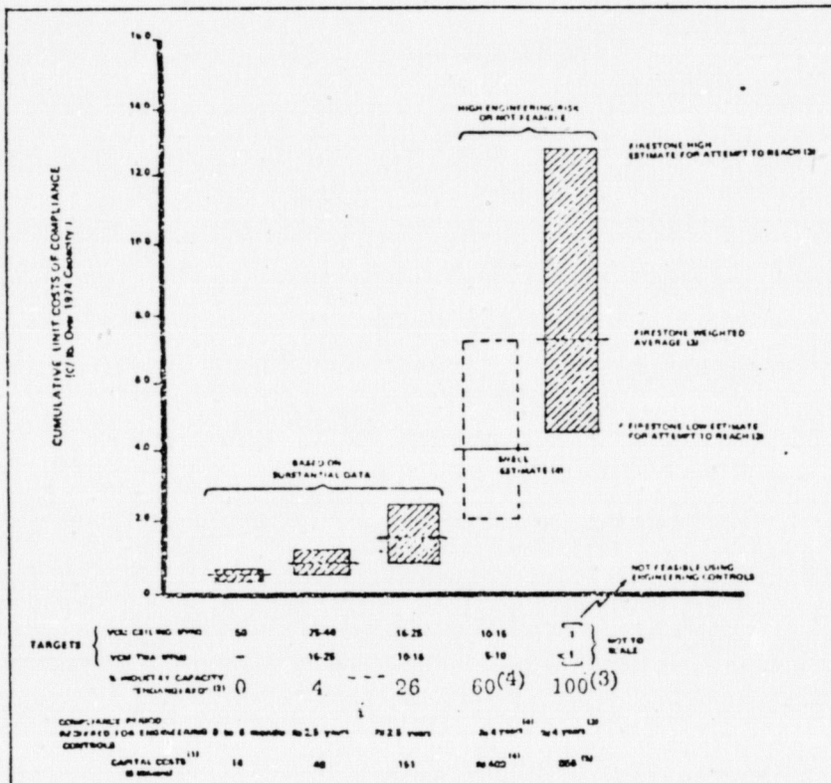
The table indicates the rapid rise in costs associated with attempting to reach the technologically infeasible "no detectable" levels beyond the 10 ppm ceiling and 2 - 5 ppm TWA target level.

Exhibit VI-1, on the following page, presents a similar discussion for the PVC industry.

EXHIBIT VI-1

USEGL/OSHA

PVC INDUSTRY CLAIMED ANNUAL COSTS TO ACHIEVE VCM TARGET LEVELS AND SUSTAIN 1974 CAPACITY (1)



ECONOMIC IMPACT CRITERIA

PLANTS LIKELY TO BE MOST "ENDANGERED"(2)

- Highest compliance costs
- Plant located in cold climate
- Old plant
- Small plant
- Small reactors
- Copolymer, emulsion or latex resin production (High free monomer)
- Small company
- Merchant sales
- Slackening demand

PLANTS LIKELY TO BE LEAST "ENDANGERED"(2)

- Lowest compliance costs
- Plant located in warm climate
- Modern plant with automation
- Large reactors
- Bulk or suspension resin production
- Large company
- Large plant
- Captive use of PVC
- Highly disciplined plant personnel

NOTES:

(1) ESTIMATES INCLUDE COSTS OF ENGINEERING CONTROLS, PERSONAL PROTECTIVE AND MONITORING EQUIPMENT AS WELL AS COSTS DUE TO PRODUCTIVITY LOSSES

(2) ENDANGERED MANAGEMENT WILL SERIOUSLY CONSIDER A PLANT SHUTDOWN

(3) FIRESTONE PROVIDED COST ESTIMATES RELATED TO "NO DETECTABLE" VCM LEVEL FOR AN ATTEMPT PRIMARILY BASED ON ENGINEERING CONTROLS, CONCLUDING INFEASIBILITY AND INDICATING THAT FIRESTONE PLANTS WOULD BE ALSO "ENDANGERED"

(4) SHELL ESTIMATE BASED ON INTERPOLATION OF INDUSTRY DATA AND JUDGEMENTAL ASSESSMENT OF THE ECONOMIC IMPACT CRITERIA ABOVE

(5) SHELL ORDER OF MAGNITUDE PROJECTION FOR THE INDUSTRY BASED ON FIRESTONE DATA WITH ITS LIMITATIONS

SOURCE: INDUSTRY INTERVIEWS, HEARING RECORDS AND SHELL ESTIMATES IN CHAPTER FIVE

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- For the VCM industry, the engineering control steps for OSHA compliance are significantly the same as those potentially used for air pollution control. Therefore, appreciable air pollution control costs are automatically accounted for by OSHA compliance.

- For the PVC industry, engineering control steps from the 50 ppm VCM ceiling level to the 15 - 25 ppm ceiling with 10 - 15 ppm TWA primarily address OSHA compliance, but significant air pollution control benefits are gained, especially at lower levels.

3. AREA MONITORING, PARTICULARLY IN PVC PLANTS IS RECOMMENDED TO OSHA AS A COMPLIANCE REQUIREMENT REGARDLESS OF THE TARGET LEVEL SELECTED BY OSHA

- Automatic Sequential Monitoring Systems (ASMS) can serve as a long term data collection system for an entire plant.

  - The ASMS can analyze an air sample from a particular point in the plant in 1 to 3 minutes with potential for at least 10 point monitoring.

  - The ASMS can be used to provide correlation with personnel monitoring data of actual worker exposure. In addition, it can be used to provide a permanent record of VCM levels, provide alarms in case of exceeding ceiling values, serve as a means to initially identify the general sources of VCM releases, and to monitor progress in complying with OSHA requirements.

  - A system installed in the polymerization building can provide warning to work personnel in that area if VCM levels have gone above ceiling levels.

  - Response to alarm can be standardized. These steps could include donning of personal protective equipment, investigation using leak detectors, isolating the point of VCM release and corrective maintenance.

4. IT IS RECOMMENDED THAT OSHA ESTABLISH PHASED REQUIREMENTS FOR REACHING VCM TARGET LEVELS TO ALLOW THE COLLECTION OF ADDITIONAL VCM MONITORING DATA TO FULLY ASSESS THE EFFICIENCY OF THE CORRECTIVE STEPS, SUBJECT TO REVIEW IN LIGHT OF CURRENT MEDICAL FINDINGS, AND AS THEY BECOME AVAILABLE

- The currently available data base particularly for VCM monitoring, is relatively small. In addition, the technology required for compliance with the lower VCM levels is not yet proven. Consequently, considerable risks exist as to the efficacy of engineering controls even for levels other than "no detectable", which is not technologically feasible.

- A phased compliance plan would allow for the assessment of the efficiency of corrective steps already taken by industry. In any event, significant lead times exist for hardware required for engineering controls.

- The phased compliance plan should be reviewed in light of current and emerging medical findings.

- A possible result of a phased compliance plan would be to spread the costs of compliance over periods of time. This may be desirable considering that the VCM and PVC price impacts may be of the same order of magnitude as the price results of the "energy crisis".

- Developmental efforts should be encouraged to improve techniques in personal protective devices, monitoring systems, and residual monomer reductions.

* * * * *

The Appendices supporting the report follow in a separate volume.

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APPENDICES
TO
DRAFT FINAL REPORT

ECONOMIC IMPACT STUDIES OF THE EFFECTS OF PROPOSED OSHA STANDARDS FOR VINYL CHLORIDE

Contract No. L/A 74-167

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September 13, 1974

USA

APPENDICES

A - DETAILED PROCESS DESCRIPTIONS AND PROCEDURES

B - EXPOSURE DATA FOR POLYVINYL CHLORIDE (PVC) AND VINYL CHLORIDE MONOMER (VCM) PLANTS

C - ECONOMIC DETAILS

D - PERSONAL PROTECTIVE EQUIPMENT AND HYGIENE

E - MONITORING EQUIPMENT

F - MEDICAL SURVEILLANCE OF EMPLOYEES

G - SAFETY AWARENESS PROGRAMS

H - NIOSH RECOMMENDED OCCUPATIONAL HEALTH STANDARD FOR THE MANUFACTURE OF SYNTHETIC POLYMER FROM VINYL CHLORIDE

APPENDIX A

DETAILED PROCESS DESCRIPTIONS AND PROCEDURES

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APPENDIX A

DETAILED PROCESS DESCRIPTIONS AND PROCEDURES

This Appendix presents design details, discussion of critical technological aspects and operating procedures regarding polyvinyl chloride (PVC) manufacture. A list of exhibits follows:

- Exhibit A-1 presents the receiving, storing and distributing of vinyl chloride monomer (VCM) as it reaches the Union Carbide Corporation. Monitoring for the vinyl chloride concentration is noted. The unloading mechanism along with the storage parameters are also noted in this exhibit. The special features that are provided to minimize personnel exposure is summarized herein.

- Exhibit A-2 presents a flow diagram of tank car unloading. This schematic is of advanced practice using spot ventilation.

- Exhibit A-3 deals with reactor design showing a technological overview by Snell.

- Exhibit A-4 provides a comparison of Conoco's large reactor PVC technology with historical reactor technology.

- Exhibit A-5 presents a detailed diagram of an older polymerizer design.

- Exhibit A-6 presents a Pfaudler Glasteel Polymerizer, a modern polymerizer design.

- Exhibit A-7 is a broad discussion of monomer stripping technology.

- Exhibit A-8 is a typical schematic for polyvinyl chloride operator movements and plant layout.

- Exhibit A-9 presents a flow diagram for the PVC emulsion process.

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EXHIBIT A-1(1)

USDOL/OSHA

RECEIVING, STORING AND DISTRIBUTING
VINYL CHLORIDE MONOMER-AFTER UNION CARBIDE

1. DESCRIPTION

Union Carbide Corporation receives vinyl chloride at South Charleston, West Virginia in 48,000-gallon tank cars shipped from Freeport, Texas. Due to the size of the car only five tank cars are unloaded per week in an open area used for unloading various chemical tank cars. Monitoring this operation on three consecutive car unloadings yielded the following results:

Date	Operation	Time Required minutes	Sample Time minutes	Concentration ppm
June 28, 1974	Hookup Car	20	20	4
	Disconnect Car	15	15	15
July 2, 1974	Hookup Car	19	19	6
	Disconnect Car	8	8	< 1
July 3, 1974	Hookup Car	22	22	8
	Disconnect Car	5	5	< 1

Vinyl chloride monomer is received by railroad tank car into a storage area located outside the boundaries of the plant proper. It is unloaded into a refrigerated sphere from which it is pumped to the consuming units.

Unloading is accomplished by equalizing the pressures in the tank car and the storage sphere and then applying vaporized vinyl chloride to the vapor space in the tank car. This provides positive suction pressure on the pump which transfers vinyl chloride to the storage sphere. After all the liquid has been removed from the tank car, a compressor pumps vinyl chloride vapors from the car to a condenser and the condensed liquid is then pumped to the sphere. The vapor pressure in the car is reduced to 5 psig, and the car is then returned to the vinyl chloride supplier for refilling.

The vinyl chloride in the sphere is maintained under its own vapor pressure (maximum of 29 psig) at a maximum temperature of 15° C by the use of refrigeration, with vinyl chloride serving as the refrigerant.

Transfer pumps and piping transfer vinyl chloride to the consuming units as required.

2. SPECIAL FEATURES PROVIDED TO MINIMIZE EXPOSURE OF PERSONNEL

General

(1) The receiving and storage area is remote from the consuming units.

(2) A high degree of automation is employed, so that there is little need for operators to be near the tank car or the sphere while unloading proceeds.

(3) Nitrogen is not employed as a pressurizing medium, so there is very little venting to rid the system of inert gas during unloading or loading by the supplier.

(4) Safety valve discharges and other vent streams are piped to a remote, elevated loaction for discharge.

(5) All pumps handling vinyl chloride are provided with mechanical seals to minimize leakage.

(6) Vent and drain valves not required for normal operation are maintained in closed position and plugged with pipe plugs.

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Tank Cars

(7) The tank cars are provided with dip tubes for top discharge only. The dip tubes are provided with excess-flow check valves; if the flow exceeds a pre-established value, the valve automatically closes.

(8) The tank cars are provided with a tape liquid-level device, which eliminates the need for venting vinyl chloride in determining the liquid level in the car.

Sphere

(9) The sphere is located in a seperately diked area, with sufficient capacity to contain the entire contents of the sphere.

(10) Lines leading into the sphere are provided with check valves, and discharge lines from the sphere are provided with excess-flow check valves.

(11) The sphere and associated piping is insulated for 15° C maximum temperature; the insulation is such that it will not decompose if subjected to fire.

(12) The sphere is provided with water spray protection.

(13) The sphere is equipped with a refrigerated vent condenser (-20° C) through which inert gases are vented to the atmosphere.